Eng.d by W. G. Jackman

GEORGE STEERS.

SHIPBUILDER.

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APP

DICTIONARY

OF

MACHINES, MECHANICS, ENGINE-WORK,

AND

ENGINEERING.

ILLUSTRATED WITH FOUR THOUSAND ENGRAVINGS ON WOOD.

IN TWO VOLUMES.

VOL. I.

NEW EDITION, WITH APPENDIX.

NEW YORK:
D. APPLETON & CO., 90, 92 & 94 GRAND STREET.
1869.

PUBLISHERS' PREFACE.

TO THE SECOND EDITION.

In presenting to the public a new edition of the "Dictionary of Mechanics, Machines, Engine Work, and Engineering," the publishers have thought it necessary that the whole work should be revised; that those novelties which were presented in the original work, and have not stood the test of use, should be struck out; those processes which have been superseded, should give place to those at present employed; and that those new machines which have not as yet been fully tested by time, but bid fair to be of practical value, as well as older machines previously omitted, should be added.

They are aware that in the first work many errors both in commission and in omission crept in—errors in judgment, and errors in arrangement—that though in general standard authors were drawn from, yet credit was often not given to the authority in the article itself. Time, experience, and consultation with persons of practical minds, have helped to correct errors in judgment. As to the arrangement, many articles were introduced into the original edition under their least characteristic heads; references were not full, often wrong. This has been remedied: the captions of articles have been changed, references have been made fuller and more accurate, and we trust that the knowledge contained in this work may be much more available.

With reference to the citation of authorities, the publishers are aware that in such a work as this, being but a compilation of abstracts, without in every case the full carrying out of the reasoning *ab initio,* the value of the results depends on the author; in the

same way, when the results of experiments are given, it is of the utmost importance that the name of the experimenter should be given. Readers prefer to exercise their own judgment in this matter to the *ipse dixit* of any editor or editors that could be brought to the compilation of this work. In this view, authorities have been supplied to the older articles as far as possible, and invariably to the new.

With the above prunings, the supplying of omissions, and the introduction of much new matter, to a work containing as much really valuable material as any of its class, the publishers offer the present edition with confidence, as worthy of the appreciation of the public.

PREFACE.

Encyclopædias and Dictionaries of Art have now become so popular, and their advantages so thoroughly tested, that it is entirely unnecessary to usher in the present work by dwelling on the peculiar merits of such publications. Every such work marks the era, or defines the position of the sciences treated, at its time of publication; and, in the lapse of years, is record of a step by which such sciences have advanced, affording material for history rather than practical working examples. On this account the older encyclopædias have become almost useless to the practical man of the present day; but the later the works, the greater their value—provided they are, as they should be, latest records of the progress of science.

No work like the one now offered to the public has ever originated here; and of the foreign works republished, none occupy the same ground, or exhibit, in the slightest degree, the state of mechanical arts in this country. The Dictionary is intended to be a Dictionary of Machines, Mechanics, Engine-work and Engineering; to present concisely and compendiously the details of valuable machines in actual use, the laws of matter and their application, the construction and proportion of parts of engines and mill-work, together with the most successful and useful examples in engineering.

In the progress of nations, it has always been remarked that the more liberal the government, the more rapid are the strides and the greater the advance in mechanical and industrial pursuits, and nowhere in history can a more brilliant illustration of this be found than in the progress of our own country; rich in natural resources, under a free and beneficent government, industry is encouraged and protected, yet comparatively sparsely populated, the country cannot, to the fullest extent, develop its resources or compete with the overstocked and poorly paid population of the older countries, unless machines are brought to supply the place of manual labor. Without encroaching on the grounds of Free Trade or Protection, it is evident that, to stand on fair ground with our competitors, we must understand the machines and processes employed by them, that these machines must be adapted or improved by us if possible, or new ones invented better to suit our resources and develop them.

To show, therefore, the advance of the mechanical arts both here and abroad, to define their exact position at the present time as far as possible, but more particularly in regard to machinery, to make, as it were, a "World Industrial Exhibition" of useful machines, and a record of their application, is the object of the present work. For this purpose the editors have drawn from the publications of all countries distinguished in mechanical pursuits. Care has been taken, in selection, to admit only such as are considered standard and practical. In many cases, credit has been given for these selections at the end of the articles; annexed also, a list of the books is given, from which selections were made. But credit is to be given especially to the Glasgow Engineer's and Machinist's Assistant, Bourne on the Steam-Engine, Holtzapffel's Turning and Mechanical Manipulation, Allgemeine Maschinen Encyclopädie, from which very able articles have been drawn.

But whilst we have drawn largely from foreign works, we have not been unmindful of our own progress in mechanism and engineering. Many patentees of valuable machines have kindly afforded us drawings and descriptions, among whom we would name

E. B. Bigelow, Esq., Henry Burden, Wm. Mason, G. H. Corliss, John J. Howe, and many others. Very many drawings and specifications have been taken from the Patent Office, and descriptions will be found in this work of machines which cannot be seen in operation; as, from a mistaken consideration of the patentees, they are not open to inspection of visitors. We are also under obligations to Wm. A. Burke, of the Lowell Machine Shop, Caleb M. Marvel, of the Essex Machine Shop, and Wm. Ellis, of the Washington Navy Yard, for drawings and descriptions of machines.

In the Engine department, we are under obligations to Mr. Copeland for the drawings and descriptions of the steamer Pacific. In Engineering, we owe much to the liberality of William J. McAlpine, in furnishing us with the description of the Dry Dock at Brooklyn, and the machinery used in its construction, together with the experiments made on the strength of the gates. The article Gold has been furnished by a distinguished metallurgist. The article on Metallurgy is by F. Overman, whose work on Iron stands deservedly high. The original communications have been numerous and valuable, and the publishers have spared neither labor nor expense to make the work what it should be.

The illustrations have all been engraved expressly for the work, as large as the page would admit, and sufficiently distinct and in detail to answer for working drawings.

The work is intended more directly for the practical and working man, and for those interested in industrial pursuits; but to all classes it will be found important and instructive. It will show how far the world has progressed in mechanical science—the science of automatic labor, the science which is destined to raise our country to the most elevated position in the world, to ennoble the mechanic and artisan, and to extend and diffuse knowledge.

Among the works from which materials have been selected may be mentioned the following:

Annales des Ponts et Chaussées. Bibliothèque des Arts Industriels: (Masson, Paris.) Civil Engineer and Architect's Journal: (London.) Engineer and Machinist's Assistant: (Blackie, Glasgow.) Publication Industrielle: (Armengaud Ainé, Paris.) Jamieson's Mechanics of Fluids. Treatise on Mechanics: (Poisson.) Allgemeine Bauzeitung mit Abbildungen: (Förster, Wien.) Organ für die Fortschritte des Eisenbahnwesens in technischer Beziehung: (Von Waldegg, Wiesbaden.) Glasgow Practical Mechanic. Silliman's Journal. Allgemeine Maschinen-Encyclopädie—Hülsse: (Leipzig.) Cotton Manufacture of Great Britain and America contrasted. Holtzapffel's Turning and Mechanical Manipulation. The Steam-Engine: (J. Bourne.) Eisenbahn-Zeitung: (Stuttgart.) Tredgold on the Steam-Engine. Dictionnaire des Arts et Manufactures: (Laboulaye, Paris.) Origin and Progress of Steam Navigation: (Woodcroft.) Essai sur l'Industrie des Matières Textiles: (Michel Alcan, Paris.) Griers' Mechanic's Pocket Dictionary. Templeton's Millwrights and Engineer's Pocket Companion. Marine Steam-Engine: (Brown.) Weisbach's Mechanics and Engineering. Barlow on Strength of Materials. Hann's Mechanics. Mechanical Principles of Engineering and Architecture: (Mosely.) Journal of the Franklin Institute. The Transactions of the Institute of Civil Engineers: (London.) The Artisan. Quarterly Papers on Engineering: (Published by Weale, London.) Imperial Dictionary —Blackie: (Glasgow.) Professional Papers of the Corps of Royal Engineers. Student's Guide to the Locomotive-Engine. Railway Engine and Carriage-Wheels: (Barlow, London.) Recueil des Machines Instrumens et Appareils: (Le Blanc, Paris.) Buchanan on Mill-Work. Practical Examples of Modern Tools and Machines: (G. Rennie.) Repertoire de l'Industrie Française et Etrangère: (L. Mathias, Paris.) Treatise on the Manufacture of Gas: (Cleg, London.) Hodge on the Steam-Engine. Scientific American. Railroad Journal: (New York.) American Artisan. Mechanics' Magazine: (London.) Nicholson's (Peter) Dictionary of Architecture. Dictionnaire de Marine à Voiles et à Vapeur: (De Bonnefoux, Paris.) Conway and Menai Tubular Bridges: (Fairbairn.) Brees' Railway Practice. Barlow's Mathematical Dictionary. Bowditch's Navigation. Gregory's Mathematics for Practical Men. Engineers' and Mechanics' Encyclopædia: (Luke Herbert.) Patent Journal: (London.) Brees' Glossary of Engineering. Encyclopædia of Civil Engineering: (Cresy.) Craddock's Lectures on the Steam-Engine. Assistant Engineer's Railway Guide: (Haskoll.) Mechanical Principia: (Leonard.) Weale's Mathematical Tables.

A DICTIONARY

OF

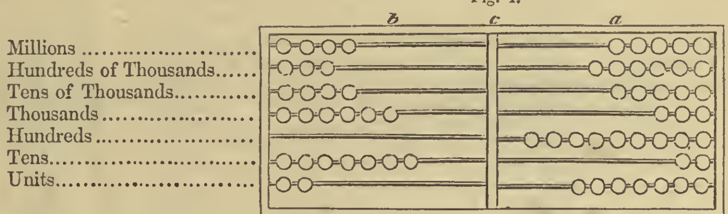
MACHINES, MECHANICS, ENGINE-WORK, AND ENGINEERING.

AAM. A measure of liquids among the Dutch, equal 288 pints.

ABACUS. An instrument employed by the ancients for facilitating calculations; similar to that now frequently employed for teaching children the rudiments of arithmetic, and which is commonly sold in our stationers' shops. It usually consists of twelve parallel wires, fixed in a light rectangular frame; each wire carrying 12 beads or balls. There are thus 12 times 12, answering to the common multiplication table, all the results of which it demonstrates to the dullest capacity. All the operations of addition or subtraction are likewise performed by it, by merely moving the beads from one side to the other of the frame. By thus smoothing the difficulties of acquiring arithmetical knowledge at the very outset, and rendering it quite obvious and amusing at the same time, the apparatus becomes one of considerable importance in education.

Another kind of Abacus consists of a series of parallel wires fixed in a frame like the former. On each wire there are nine little balls; the lowest stand for *units*, the next above for *tens*, the next *hun-*

Fig. 1.



dreds, and so on up to any number. The frame is divided into two compartments, *a* and *b*, by a cross wire at *c*, which is sufficiently raised above the wires to allow the little balls to slide under it. Suppose the whole 63 balls to be placed in the compartment *a*, and it be proposed to note the sum of 4,346,072 it is effected by sliding the balls shown in *b* from their previous situation in *a*.

ABACUS. The *plate* or shallow block forming the uppermost member of a capital, so called for the sake of distinction, for when a similar one is placed beneath the base of a column, it is called a *plinth*.

ABELE. See Woods, *varieties of*.

ABUTMENT is a term commonly applied by engineers to those fixed parts of mechanism used to resist a thrust. In the case of Bridges the term is applied to the land pier, whether subject to thrust or not.

ACACIA. See Woods, *varieties of*.

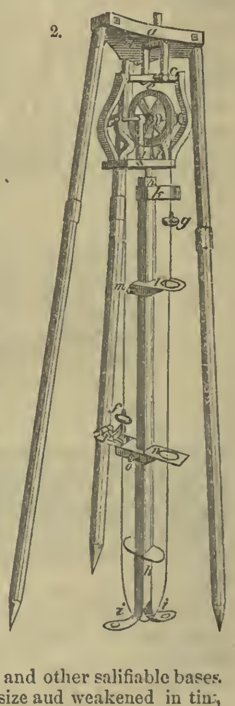
ACCELERATION is the increase of velocity in a moving body, caused by the continued action of the motive force. When bodies in motion pass through equal spaces in equal times, or, in other words, when the velocity of the body is the same during the period that the body is in motion, it is termed uniform motion, of which we have a familiar instance in the motion of the hands of a clock over the face of it; but a more correct illustration is the revolution of the earth on its axis. In the case of a body moving through unequal spaces in equal times, or with a varying velocity, if the velocity increase with the duration of the motion, it is termed accelerated motion; but if it decrease with the duration of the motion, it is termed retarded motion. A stone thrown up in the air, affords an illustration of both these cases, the motion during the ascent being retarded by the force of gravity, and accelerated by the same during the descent of the stone. All bodies have a tendency to preserve their state, either of rest or of motion; so that if a body were set in motion, and the moving force were withdrawn, the body, if unopposed by any force, would continue to move with the same velocity it had acquired at the instant the moving force was withdrawn. And if a body in motion be acted upon by a constant force, (as the

force of gravity,) the motion becomes accelerated, the velocity increasing as the times, and the whole spaces passed through increasing as the square of the times; whilst the proportional spaces passed through during equal portions of time, will be as the odd numbers, 1, 3, 5, 7, &c.; and the space passed over in any portion of time will be equal to half the velocity acquired at the end of such time: which results will be better brought to view in the following Table:

Times.	Velocities.	Spaces for each Time.	Total Space
1	1	1	$1 = 1^2$
2	2	3	$3 + 1 = 4 = 2^2$
3	3	5	$5 + 3 + 1 = 9 = 3^2$
4	4	7	$7 + 5 + 3 + 1 = 16 = 4^2$

It has been ascertained by experiment, that a body falling freely by its own weight from a state of rest, will descend through 16 feet 1 inch in the first second of time, and will have acquired a velocity of 32⅙ feet; but from the rapidity with which the velocity increases, we cannot extend the experiment, for in only four seconds a body falling freely would pass through a space of 256 feet. But by an ingenious contrivance of Mr. Atwood, the laws of motion above laid down may be verified experimentally. The machine is called "Atwood's machine," after the name of the inventor; and the principle of its action consists in counteracting a portion of the gravitating power of a body, by the gravitating power of a smaller body; so that the absolute velocity, and the spaces passed through, shall be less than in the case of bodies descending freely, whilst, as the force is constant, the same ratio of progression will hold in both cases. The annexed figure represents one of these machines: *a a a* is a triangular frame upon three moveable legs; *b*, a small platform suspended from it by a universal joint *c c*, and supporting two upright standards *d d*, in which the axis of a light brass wheel *e* revolves with very little friction. Over a groove in the periphery of the wheel passes a very light and pliable silk thread, from the ends of which hang two equal weights *f*, *g*. Into the under side of *b* is screwed a square rod *h*, descending to the floor, to which it is secured in a perpendicular position by small pins passing through holes in the claws at *i i*. On the face of the rod is a scale of inches; *k* is a brass guide, fixed at the upper part of the rod *h*, so that when the top of the weight *g* touches the lower side of *k*, the under side of *g* is on a level with the top, or commencement of the scale; *l* is a small stage, moveable along the rod *h*, and having a hole in it sufficiently large for the weight *g* to pass: on one side is a tightening screw *m*: *n* is another moveable stage, fitted with a tightening screw *o*, as also a fork *p*, turning upon a hinge. The experiments are conducted as follows:—A small circular weight is placed upon *g*, which is pulled up to the top of the scale, and the stage *n* is screwed to the rod *h*, on a level with the lower part of the weight *f*, which is held down upon it by the fork *p*. Upon releasing *f* from the fork, the weight *g* descends with a slow, but gradually accelerated motion, and the number of inches the weight has descended, at each successive beat of a pendulum, (suspended from another triangle,) is observed upon the scale; and if the additional weight be such as to cause *g* to descend through three inches in the first second, then it will cause it to descend through one foot in two seconds, and through 6¼ feet in five seconds. If the additional weight be removed, and a small bar of equal weight, but of a length exceeding the diameter of the hole in *l*, be placed upon *g*, and the stage *l* be set at any division of the scale, at which the weight would arrive at the end of any number of seconds, the stage will intercept the bar in its descent, and the weight will continue to descend with the velocity it had acquired upon reaching *l*. Thus, if the velocity at the end of the second second be two feet, in which case the weight would have descended one foot in that time, if the stage be set at one foot upon the scale, it will intercept the bar at the end of the second second, and the weight *g* will move with a uniform velocity of two feet per second, through the remaining portion of its descent. If it is required to illustrate the case of retarded motion, the small circular weight is placed upon the weight *g*, and a similar small weight upon the weight *f*, so that *g*, still outweighing *f*, will descend; but as soon as the stage *l* intercepts the bar with the small weight upon it, *f* becomes the heaviest, and *g* will descend with a velocity decreasing as the squares of the times, counted from the time of *g* passing the stage *l*.

2.



ACIDS. Sour substances, or in chemistry such as neutralize the alkalis and other salifiable bases.

AERIAL PERSPECTIVE, is that which presents objects diminished in size and weakened in tint, in proportion to their distance from the eye: but the term relates principally to the color.

AFFINITY, a term used in chemistry to denote that kind of attraction by which the particles of different bodies unite, and form a compound possessing properties distinct from any of the substances which compose it. Thus, when an acid and alkali combine, a new substance is formed, called a salt, perfectly different in its chemical properties from either an acid or an alkali; and the tendency which these have to unite, is said to be in consequence of affinity.

AFRICAN BLACKWOOD. See Woods, *varieties of.*

AIR. Pure air consists almost entirely of nitrogen and oxygen gases, with a very small portion of carbonic acid gas. Of 100 parts of air, reckoning by weight, 75.55 parts are nitrogen, 23.32 oxygen, and 1.13 carbonic acid and watery vapor. Both as respects weight and bulk, nitrogen forms the chief ingredient of the atmosphere.

The weight or pressure of the atmosphere is equal to the weight of a column of water 34 feet in

height, or to a column of mercury 30 inches in height, or 14.7 lbs. per square inch at a mean temperature. But air and all kinds of gases are rendered lighter by the application of heat, for then the particles of the mass are repelled from each other or rarefied, and occupy a greater space. Rarefied air, being specifically lightest, mounts above that of common density; hence, change of temperature is the principal cause of winds. If air be very suddenly compressed into a small compass, the heat given out is so considerable as to be sufficient to ignite inflammable substances. This property has been turned to advantage in an apparatus denominated, "An Instantaneous Light Machine," which consists of a piston accurately fitted and worked in a cylinder, by the sudden stroke of which the volume of air contained in the cylinder becomes so much compressed as to give out sufficient heat to set fire to a piece of the substance termed German tinder.

For the necessity of air in respiration and combustion, see WARMING and VENTILATION.

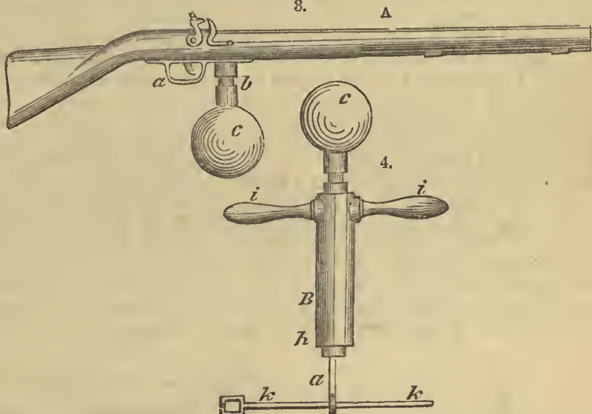
AIR CHAMBER, See PUMPING ENGINES.

AIR ESCAPE, a simple and ingenious contrivance for letting off the air from water-pipes. If a range of water-pipes be led over a rising ground, it will be found that air will collect in the higher parts and obstruct the progress of the water; to remedy which inconvenience the Air Escape is employed. A hollow vessel is attached to the upper part of the pipe, in the top of which vessel there is fixed a ball cock, adjusted in such a way, that when any air collects in the pipe, it will ascend into the vessel, and by displacing the water, cause the ball to descend, and thus open the cock, when the air is allowed to escape. No water, however, can escape, for when that fluid rises in the vessel above a certain height, the ball rises and shuts the cock; new air then collects, displaces the water, lowers the ball, the cock is opened, and it again escapes.

AIR-GUN. A machine in which highly-compressed air is substituted for gunpowder to expel the ball, which will be projected forward with greater or less velocity, according to the state of condensation, and the weight of the body projected.

It consists of a lock, stock, barrel, ramrod, &c., of about the size and weight of a common fowling-piece. Under the lock at *b* is screwed a hollow copper ball *c*, perfectly air-tight. This ball is fully charged with condensed air, by means of the syringe B, previous to its being applied to the tube at *b*. Being charged and screwed on as above stated, if a bullet be rammed down in the barrel, and the trigger *a* be pulled, the pin in *b* will, by the spring-work in the lock, forcibly strike out into the ball, and thence by pushing it suddenly, a valve within it will let out a portion of the condensed air, which, rushing through the aperture in the lock, will act forcibly against the ball, impelling it to the distance of 60 or 70 yards, or farther if the air be strongly compressed. At every discharge only a portion of the air escapes from the ball; therefore, by re-cocking the piece another discharge may be made, which may be repeated for a number of times proportioned to the size of the ball. The air in the copper ball is condensed by the syringe B in the following manner. The ball is screwed quite close on the top of the syringe; at the end of the steel-pointed rod *a* is a stout ring, through which passes the rod *k*; upon this rod the feet should be firmly set; then the hands are to be applied to the two handles *i i* fixed on the side of the barrel of the syringe, when, by moving the barrel B steadily up and down on the rod *a*, the ball *c* will become charged with condensed air, and the progress of condensation may be estimated by the increasing difficulty in forcing down the syringe. At the end of the rod *k* is usually a square hole, that the rod may serve as a key for attaching the ball to either the gun or syringe. In the inside of the ball is fixed a valve and spring, which gives way to the admission of the air, but upon its emission, comes close up to the orifice, shutting out the external air. The piston-rod works air-tight by a collar of leather on it, in the barrel B; it is therefore obvious, that when the barrel is drawn up, the air will rush in at the hole *h*; when it is pushed down, it will have no other way to pass from the pressure of the piston but into the ball *c* at the top. The barrel being drawn up, the operation is repeated, until the condensation is so great as to resist the action of the piston.

3.



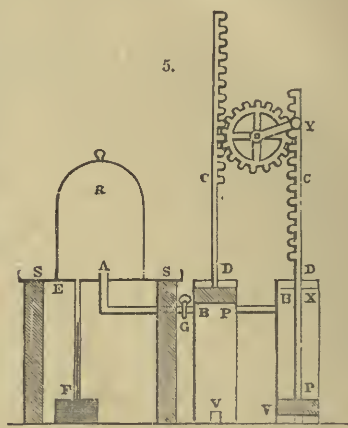
AIR-VALVE, a valve commonly applied to steam-boilers for the purpose of preventing the formation of a vacuum when the steam happens to be condensed within the boiler. The mode of action of these valves is very simple. A valve in the top of the boiler opening inwards, is kept shut by a counterweight at the end of a lever; but whenever the steam in the boiler happens to be condensed, a vacuum is formed, and the air-valve is opened by the pressure of the atmosphere, consequently the air enters and destroys the vacuum. The interior of the boiler being allowed to remain in the state of vacuum, the atmospheric pressure from without might cause its sides to collapse, and thus effect the destruction of the boiler.

AIR-PUMP. An apparatus to extract or exhaust the air from a vessel, to produce a vacuum.

Fig. 5 is a sectional view of the common form of the Air-pump. R is a bell-shaped glass vessel, open only at the bottom, and whose rim is ground perfectly flat, so that it may rest on every point, on a brass plate S S. which is likewise ground to a flat surface, so that when a little hog's-lard is

rubbed upon the edge of the glass vessel, commonly called the receiver, and then the rim placed, by a kind of circular sliding motion, upon the brass plate, no air can pass in or out of the receiver, between its edge and the plate. Through the centre of the brass plate there is drilled an orifice A, from which orifice there is led a pipe AB, forming a communication between the receiver R and the interior of the cylinder BPV, which communication may be opened or closed by means of a stop-cock at G. The cylinder or barrel BPV is furnished with a piston BP accurately fitted to the cylinder, but capable of free motion up and down, which motion is effected by means of a piston-rod DC, which moves through a stuffed or air-tight collar at D. The bottom of the cylinder or barrel is furnished with a valve V opening outwards. This cylinder communicates with another BXPV, constructed and furnished in similar manner; and the two piston-rods are provided with racks C C at the top, the teeth of which are acted upon by those of a wheel placed between them, as may be seen in the figure. Let us now attend to the mode of action. Suppose the stop-cock at G open, and the pistons as they are in the figure. The piston BP being at the top, a free communication is formed between the receiver R and the first cylinder, and the piston being pushed down past the orifice at B, the air contained in the cylinder or barrel will be forced into less space or compressed, and of course its elastic force increased. In consequence of this increased elasticity, the valve at V will be opened, and the air expelled. When the piston is lifted, this valve will be shut by the pressure of the atmospheric air without thus a portion of the air which was contained in the receiver, communication pipe, and barrel, has been expelled, and that which remains will consequently be less dense; another stroke of the piston will diminish the density still more; and this process may be continued until the density be so diminished, that when compressed by the descent of the piston to the bottom of the barrel, its elastic force is only sufficient to open the valve V. It will be easily seen, that the exhaustion of the air in the receiver depends on the elasticity of the air; for when the piston descends and expels the air contained within the barrel, which it will do completely, if it go to the bottom, and then in returning, the valve V being shut, a vacuum will be formed in the barrel until the piston in its ascent passes the orifice B, when the air within the receiver will expand and fill the whole cavity. The operation of the second barrel and piston is precisely similar to that of the first, so that when the one is understood, the other requires no explanation.

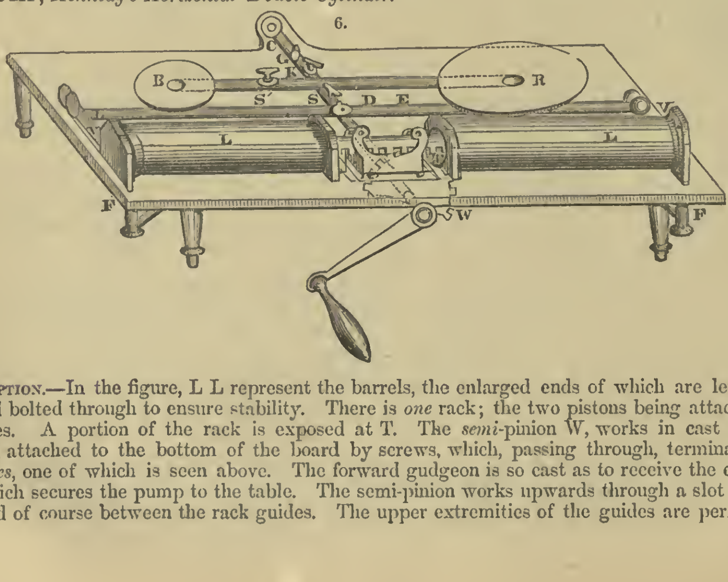
5.



The degree of exhaustion will depend upon the workmanship of the pump, the number of strokes of the piston, and the relative capacities of the receiver and barrels; but perhaps in no case can the vacuum in the receiver be made perfect. For the purpose of determining the degree of exhaustion, a mercurial gauge is employed, which acts on a similar principle with the common barometer. A glass tube EF, rests in a basin of mercury F, and its upper orifice opens into the brass plate SS. When the exhaustion of the receiver has commenced, the pressure of the air in the receiver must be less than that of the atmosphere without. Wherefore, since the air in the receiver presses the mercury down the tube, and the atmosphere pressing on the mercury in the basin forces it up the tube, with the greater force the mercury will rise in the tube, and it will rise the higher according to the difference of the density, and consequently elastic force of the air in the receiver, and that of the atmosphere.

AIR-PUMP, *Kennedy's Horizontal Double Cylinder.*

6.



Description.—In the figure, L L represent the barrels, the enlarged ends of which are let into the board and bolted through to ensure stability. There is *one* rack; the two pistons being attached to its extremities. A portion of the rack is exposed at T. The *semi*-pinion W, works in cast straps, or gudgeons, attached to the bottom of the board by screws, which, passing through, terminate in the *rack guides*, one of which is seen above. The forward gudgeon is so cast as to receive the end of the *clamp* which secures the pump to the table. The semi-pinion works upwards through a slot cut in the board, and of course between the rack guides. The upper extremities of the guides are perforated to

receive rollers, against which the back of the rack may work when necessary. None have yet been required. To the axis of the semi-pinion the handle is attached in the usual manner. The piston may be either solid or valved, and the cylinders may communicate with the plates R and B, in the way most approved by the maker. In the pump from which the sketch is taken, the pistons are solid. The farther extremities of the cylinders bear female screws, which connect with corresponding male screws on the block. On the posterior portion of each block is cut a female screw; the male of which bears the valve V V, of course opening inwards. On those portions of the blocks which project into the board are cut male screws bearing valves opening outwards. Perforated nuts over these secure the blocks to the board, and the valves against injury. At V V is attached the tube leading from the plates. D is the screw for restoring atmospheric pressure. The general stop-cock S, connects this with the parallel tube which, bearing the gauge-cock S′, forms at pleasure a communication between the plates.

The original of the figure both exhausts and condenses. The remaining letters refer to the parts used in condensing. This is effected by simply connecting, by means of tubes under the board, the valves F′, F, with a third tube passing upward to the stop-cock K. Then the air drawn in at R, will be condensed in a receiver screwed on C. The condensing gauge is borne by the screw G. This instrument is furnished thus with all the facilities for exhaustion, transfer, and condensation, without any shifting of parts.

AIR-PUMP. See ENGINES.

AIR-PIPES, an invention for clearing the holds of ships and other close places of their foul air. The contrivance is simply this: a long tube, open at both ends, is placed with one end opening into apartment to be ventilated, and the other out of it. The air in the outer end of the tube is rarefied by heat, and the dense air from the hold comes in to supply the partial vacuum, the escape of the foul air in the hold being supplied by fresh air introduced through an opening above; and this process is carried on until the air becomes everywhere equally elastic.

AJUTAGE, a tube fitted to the mouth of a vessel for the purpose of modifying the discharge of water.

ALARMS. Machines intended to give notice of danger, as from fire, from fire-damp, from lowness of water or excess of pressure in steam boilers, &c. Automatic fire alarms depend in general on some arrangements of strings traversing behind the wainscot and ceiling, which if burned off detach some mechanism connected with a bell, by which an alarm is given; the expansion of metal wire or rods is also applied for the same purpose. Burglar alarms are sometimes employed by drawing strings across passages, connected with alarm bells, or the bells are attached to doors and windows in such a manner that a slight opening of the same may cause them to strike.

For an alarm showing the presence of fire-damp, M. Chuart has made use of a ball or globe, contained in a chemical solution highly sensitive to any deterioration of the atmosphere, and acting upon a lever, which sets an index in motion, and thus shows the vitiated state of the atmosphere, whether in a mine or elsewhere, long before the common air can be so saturated with gas as to explode on the application of light. M. Chuart has added to his invention an alarum bell, which is struck by the lever when the ball is thrown off its equilibrium by the vitiated state of the atmosphere.

7.

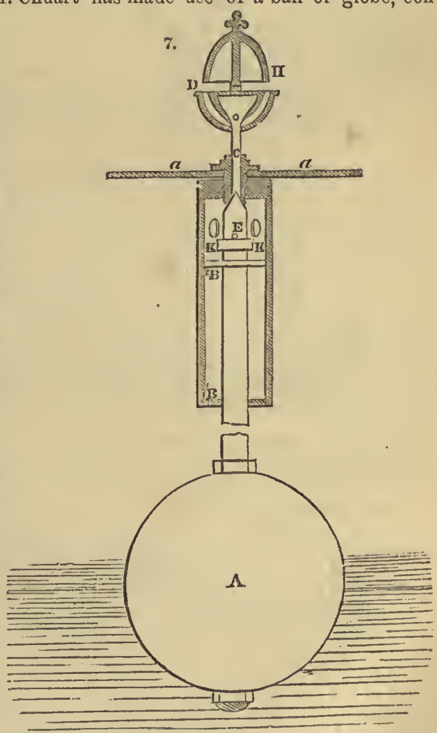


Fig. 7 is an illustration of a method proposed to give notice of the lowness of water in boilers. A is a float attached to a stem or rod which passes upwards through a tube B^1, and a diaphragm, B^2, fixed within that tube, and terminates in a conical top, which fits into the hollow pipe C, of the steam whistle D. The lower end of the whistle D is passed through an orifice in the top of the boiler, (indicated by the letters *a a*,) and screwed into the top of the tube, which is thus kept steady, if in a vertical position. E is a collar attached to the stem of the float, near the top, which, catching against the plate B^2, on the fall of the stem or rod A, prevents it from descending further. When the water falls below the safety-line, and the float along with it, the descent of the stem of the float opens the pipe C of the whistle, and allows the steam to escape, which, impinging against the bell H at top, produces the alarm required. In Dunn's alarm for boilers, the falling of the water below the proper level establishes by means of a battery a galvanic current, and rings a bell or bells in any part of the establishment in which it is desirable that notice should be given.

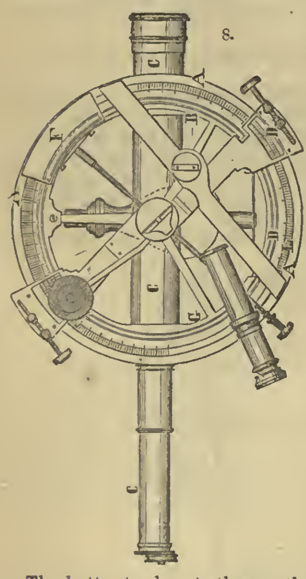
For the transmission of intelligence of fire in cities see "FIRE ALARMS."

ALDER. See WOODS, *varieties of.*

ALLOYS. Baser metals mixed with more valuable ones. See ASSAY.

ALMOND-TREE. See WOODS, *varieties of.*
ALOES-WOOD. See WOODS, *varieties of.*
ALTIMETER. Beatson's patent, for taking, measuring, and computing angles. Fig. 8 is a side elevation of this instrument. A is a broad ring of brass, to one side or the back of which a telescope, C, is affixed in a horizontal line exactly coinciding with the centre of the ring. B is a glass tube of about the sixteenth of an inch in the bore, which is let into a groove made in the front of the ring, and extends all around with the exception of about an inch or two, where a segmental air-tight junction piece F, of metal, is inserted between the two ends of the tube, which are left open, and communicate freely with the piece F. The tube is about half filled with mercury, (or other suitable fluid) which forms itself into a continuous thread of a crescent shape, with a fixed quantity of air between the two cusps. As long as the two fluids are left at liberty, they may of course be shifted round to any parts of the circle; but in the middle of the junction piece F, there is a valve, V (not seen in the figure), inserted, which is worked by a spindle and thumb-piece, from the opposite side of the instrument; and when this valve is closed, the motion of the fluid to either side of that valve is from that moment necessarily stopped. The eye-piece of the telescope is provided with darkened glasses to save the eye from the glare of the sun, and the field of view is divided in the centre by a wire, to show the line of collimation. On the front of the brass ring A, immediately outside of the groove containing the glass tube, and on opposite sides of the telescope, there are two quarter circle scales, R, and L, engraved. Both of these scales have their zero points on the same line with the axial line of the telescope, but the numbers in R run upwards from 0 to 90, while those in L run downwards from 0 to 90; the 90° in the one case (R) representing the zenith, and in the other the nadir. These scales are subdivided by two verniers, D D. The mode of using the instrument is as follows: The observer first releases the alcoholic or other fluid in the tube B from the pressure of the columns of air at each end, by turning the thumb-piece from left to right; he then directs the telescope towards the sun or other object whose altitude it is desired to ascertain, and brings the cross-wire into contact (so to speak) therewith; which having done, he turns the thumb-piece the reverse way, which fixes the mercury at the exact level it had attained at the moment of contact, the column of air in B pressing on the mercury at each end, and thus necessarily preventing the slightest displacement.

8.



The observer next proceeds to read off the indications furnished by the two scales of the instrument; he sets first down the numbers on the left-hand scale R, which come opposite to the top line of the fluid on the left-hand side, and then the numbers opposite the top line of the fluid on the right-hand side; which done, he adds the two sets of numbers together, and divides by 2, which gives the required altitude.

For example; if the

Left altitude be	46 20
Right altitude	47° 40′
The sum divided	2)94°
Would give for the desired altitude . .	47°

The necessity for taking a mean of the two readings arises from the liability of the fluids to expansion, for were no change to take place in their thermometric condition after the contact, the numbers would remain necessarily alike on both sides.

The better to show to the eye the movements of the fluids in the tube, the bottom of the groove G may be stained of a red or some other bright color.

The "Universal Altimeter" may be contained in one framework with any of the ordinary sea and land surveying instruments; as is exemplified in the fig., where it is shown combined with a common sextant.

AMBOYNA-WOOD. See WOODS, *varieties of.*
ANALYSIS. See ASSAY.
ANASTATIC PRINTING. (The term "Anastatic" means rising up, or a reproducing as it were, and very significantly does the name express the result; for by it any number—thousands upon thousands—of reproductions of any printed document may be obtained, each of which is a perfect *facsimile* of the original, no matter how elaborate the engraving may be, or how intricate the design.)

The print of which an Anastatic copy is required is first moistened with very dilute nitric acid, (one part of acid to seven of water,) and then being placed between bibulous paper, all superabundance of moisture is removed. The acid being an aqueous solution, will not attach itself to the ink on the paper, printers' ink being of an oily nature; and if the paper thus prepared be placed on a polished sheet of zinc and subjected to pressure, two results follow:—in the first place, the printed portion will leave a set-off or impression on the zinc; and secondly, the nitric acid attached to the non-printed parts of the paper will eat away and corrode the zinc, converting the whole, in fact, into a very shallow stereotype. The original being removed (perfectly uninjured), the whole zinc plate should next be smeared with gum-water, which will not stick to the printed or oily part, but will attach itself to every other portion of the plate. A charge of printers' ink being now applied, this in its turn only attaches itself to the set-off obtained from the print. The final process consists in pouring over the

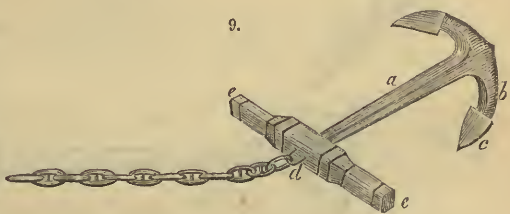
plate a solution of phosphorous acid, which etches or corrodes more deeply the non-printed portion of the zinc, and produces a surface to which printers' ink will not attach. The process is now complete, and from such a prepared zinc plate any number of impressions may be struck off.

The Anastatic process is not only applicable to the copying of the impressions made with printers' ink, but any other inks however, even the most fugitive, may be adapted to this operation; and hence, without some safeguard, the dishonest practices to which the Anastatic process might be applied would be numerous. The paper invented by Messrs Glynn & Appel afford this safeguard. It consists merely in impregnating or dying the pulp of which the paper is made with an insoluble salt of copper. After a series of experiments, the patentees preferred phosphate of copper to any other salt; and for this purpose sulphate of copper and phosphate of soda are successively mixed with the pulp, which, of course, produce an insoluble salt, the phosphate of copper. Besides this, a very small portion of a peculiar oily and non-drying soap is introduced, which affords a double protection. Should the forger attempt to submit a note or check printed on the patent paper to the Anastatic process, a film of metallic copper separates between the paper and the zinc, not only preventing a set-off, but cements the paper so strongly that the paper must be destroyed—it can only be removed in small pieces.

ANACLASTICS. That part of Optics which considers the refraction of light, and is commonly called Dioptrics.

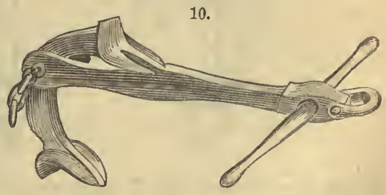
ANCHOR. A heavy curved instrument, used for retaining ships in a required position. The forms of anchors, and the materials of which they are made, are various. In many parts of the East Indies the lower part of the anchor is formed of a cross of a very strong and heavy kind of wood, the extremities of which are made pointed. About the middle of each arm of the cross is inserted a long bar of the same wood, the upper ends of which converge to a point, and are secured either by ropes or an iron hoop, and the space between the bars is filled up with stones to make the anchors sink more deeply and readily. In Spain, and in the South Seas, anchors are sometimes formed of copper, but generally in Europe they are made of forged iron. Anchors may be divided into two classes—mooring anchors, and ships' anchors. Mooring anchors are those which are laid down for a permanency in docks and harbors, and are considerably heavier than ships' anchors, from which they differ in form, having sometimes but one arm, and sometimes, instead of arms, having at the extremity a heavy circular mass of iron and no stock: these latter are called mushroom anchors. The general form of ships' anchors is shown in the annexed figure. There is a long bar of iron, *a* called the shank, from the lower extremity of which branch two curved arms *b b* in opposite directions, and forming an angle of 60° each with the shank. Upon each arm towards the end, is laid a thick triangular piece of iron *c c*, termed the *fluke*. In the upper end of the shank is an eye, through which passes a ring *d*, to which the cable is attached. The stock *e* is composed of two strong beams of wood, embracing the shank, or an iron rod passing through the shank. The stock stands at right angles to the plane of the arms, and serves to guide the anchor in its descent, so as to cause one of the flukes to enter the ground. Ships are generally provided with three large anchors, named the best bower, the small, and the sheet anchor; a smaller anchor, termed the stream anchor; and another, still smaller, named the kedge, which latter has generally an iron stock passing through an eye in the shank, secured thereto by a key, or forelock, which admits of its being readily displaced: its principal use is in changing the position of a ship in harbor, and in an operation termed kedging. From the great mass of iron in large anchors, (some weighing from 3 to 4 tons,) the perfect forging of them becomes a matter of much difficulty; as from the great heat necessary to weld such masses, the iron is liable to become "burnt" as it is termed. Workmen also cannot always observe what is going on in the forge, where the iron is exposed to ignition from the blasts of the bellows, or to the presence of sulphur in quantity among the coals. When the welding of a large mass, like the shank of an anchor, is to be completed by the sledge-hammer, the workmen are subjected to a scorching heat radiating therefrom, which renders it impossible to make a very close inspection, and the consequence frequently is, the beating up of cinders within the body of the iron. To this cause, and to burning, may be often attributed the breaking of anchors, followed too frequently by a distressing loss of lives and property. Many attempts have been made of late years to construct anchors not liable to these defects, by dividing the mass into separate parts, and by a more judicious arrangement.

9.

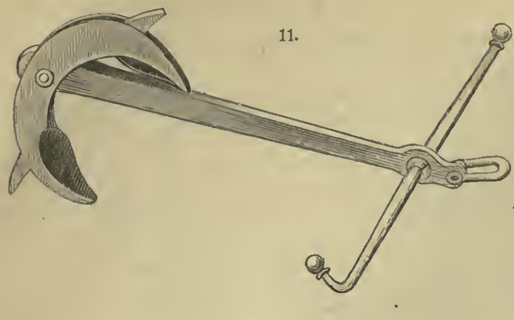


Figs. 10 and 11 represent the two most popular forms of anchors, Porter's and Bloomer & Co.'s. In both, the difficulties of the welding the shank to the arms is obviated. The construction of Bloomer & Co.'s is as follows:

10.

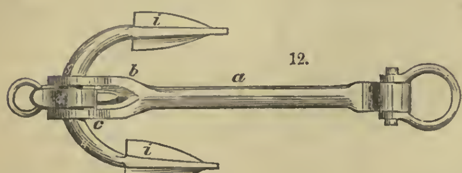


The arms or flukes of the anchor are made in *two separate pieces*, or *plates* of iron of the entire size required, which are bent to the required sweep, or angle, and secured to the shank by a bolt at the crown. The palm and toggle are constructed in one solid piece; the toggle (or horn) being bent into the required form, is passed through, between the two plates, and secured in its position by them; the point of the palm and the two pointed ends of the plates are then welded together at one heat, which completes the work. The shank is made of one solid piece, and is inserted *between* the plates of the flukes, (instead of the flukes being inserted between the two *welded jaws*, as fig. 10,) and is secured by a crown bolt.


11.

It will thus be seen that this anchor is formed with only *two welding heats*, (viz., at each point of the fluke,) and those at the places least liable to accident, and of less vital importance in case of fracture than any other part of the anchor.

One differing materially in form and construction from the ordinary anchor was invented by Mr. R. F. Hawkins, and is represented in the subjoined engravings. The shank of the anchor *a* is forked at the lower part or crown, into two parts or loops *b* and *c*, in each of which is formed a hole or eye; between the loops is a block of iron *d*, termed a crown-piece, having a circular aperture to receive the arms and a square aperture at right angles to the former, into which is screwed a stout bar of iron *e*, termed a toggle, projecting equally on each side of the crown-piece; on the end of the crown-piece, opposite to that in which is inserted the toggle, is a ring, *f* for the buoy rope. The arms *g h* are formed in one piece, and before the palms *i i* are attached, one end of the arms must be passed through the eyes in the loops of the shanks and through the eye of the crown-piece; the palms are then to be put on, and must both lie in the same plane; after which the arms are to be curved in the same plane with the palms. The crown-piece is firmly keyed to the arms, and the toggle must be of such a length and form as to make it bear firmly against the fore part of the fork in the shank, so as to prevent the crown-piece and arms from turning round upon it, and to retain them at an angle of 50° with the shank. When the anchor is let go, one end of the toggle will come in contact with the ground, which puts the flukes in a position to enter; and when the strain is upon the cable, that end of the toggle which is upwards comes in contact with the throat of the shank, and sets the anchor in the holding position, as shown in perspective at fig 14. The advantage of this mode of constructing anchors is, that both arms take the ground, and therefore the weight of metal may be diminished, and yet an equal, if not a greater effect be obtained; also, as there is no stock, and no projecting upper fluke, there is little risk of *fouling*, as it is termed; that is, of the cable entwining round the arms.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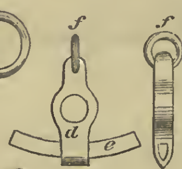
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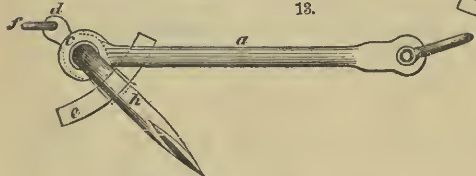
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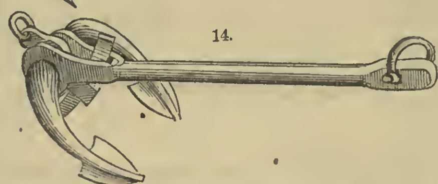
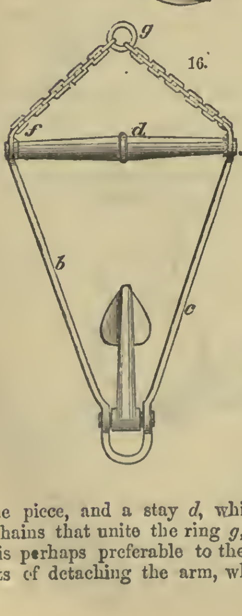

14.

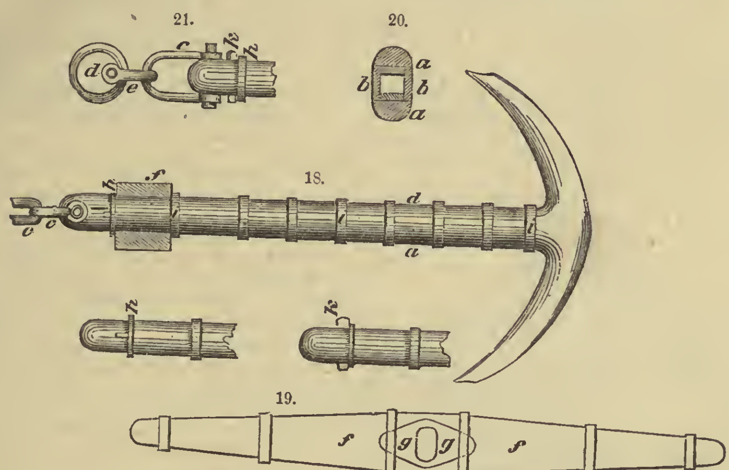

16.


17.

An anchor upon a similar principle, but of a somewhat different construction, was invented by Mr. Soames, a front and side elevation of which is exhibited in the subjoined cuts. In this anchor there is but one fluke *a*, which is T shaped, and works on a pivot in a triangular frame, composed of the two sides *b* and *c*, forged in one piece, and a stay *d*, which serves as a stock; *f f* are loops, or eyes, for the reception of the chains that unite the ring *g*, to which the cable is to be fastened. For general purposes, this anchor is perhaps preferable to the former, it being free from the objection we made to that one, as it admits of detaching the arm, which renders it more convenient to stow away; also, as the shank is

formed in two parts, instead of one of equal area, they are more easily forged soundly, and consequently less liable to breakage.

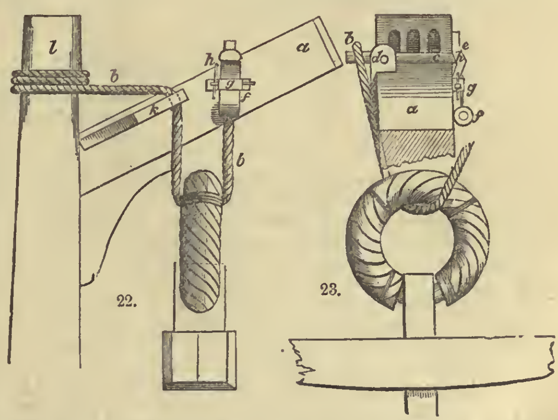
The peculiarity of the anchor proposed by W. Rogers, consists in its having a hollow shank, formed out of six bars of iron, of such a thickness as to insure the forging of them perfectly sound for anchors of the largest dimensions. Fig. 18 represents a side view of the anchor, and fig. 19 a plan of the stock. The two principal pieces *a a* are bent so as to form a part of the arms or flukes; the other four are formed into a hollow tube *b b* (as shown in section at Fig. 20) for a centre-piece, and the whole are firmly welded together at both ends of the shank. The intermediate parts are secured by strong hoops *i i*, so that every piece must bear its proportion of the entire strain. In place of the usual ring, there is a bolt and shackle *c*, Figs. 18 and 21, when the anchor is to be used with chain cables; but when hempen cables are to be used, a ring *d* is connected to the shackle *c* by an additional shackle and bolt *e*. The anchor-



stock *f* may be formed either of a single piece, or of two pieces hooped together, and is secured in its place as follows: The bolt and shackle *c* being withdrawn, the small end of the shank is passed through the eye of the stock *f*, (which is defended by an iron plate *g* on each side;) the collar *h* is then put over, and the stock is keyed up against the hoop *i* by the forelock key *k* passing through a hole in the shank;

Two improved methods of letting go anchors are described in the *Transactions of the Society of Arts.* The principle is the same in each, and consists in supporting the end of what is termed the standing part of the cat-head stopper and shank-painter, by bolts turning upon pivots, and retained in a proper position by a catch, which being withdrawn, the bolt turns upon its pivot, and the stopper slips off, by which means all risk of jamming the turns of the stopper (as in the common method of letting go the running end) is avoided; the danger to the men on the forecastle is done away, and the anchor can be let go at a moment's warning.

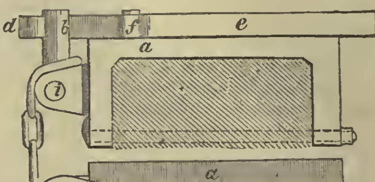
The arrangements in each of these inventions being the same, whether applied to cat-head stoppers or shank-painters, we shall therefore show one invention as applied to cat-head stoppers, and the other to shank-painters. The subjoined cuts show Capt. Burton's method of letting go a cat-head stopper. *a* is the cat-head; *b c* a bolt, turning upon a pivot *d;* the end *c* forms an oblique plane, and is held down by the clamp *e* turning upon a pivot *f*, the clamp being secured by a hasp *g* and pin *h*. The standing end of the stopper, having an eye formed in it, passes over the end *b* of the bolt *b c;* the other end of the stopper passes through the ring of the anchor, and over the thumb-cleat *k*, and is made fast round the timber-head *l*. When it is required to let go the anchor, a handspike is inserted between the thumb-cleat *k*, so as to nip the clamp *e*, and the hasp *g* is cast off; then, upon withdrawing the handspike, the bolt being no longer held by the clamp *e*, turns upon its pivot *d*, by the weight of the anchor on the stopper, and the eye of the stopper slips off the end of the bolt.



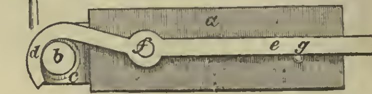
The following cut represents Mr. Spence's invention for letting go a shank-painter. Fig. 24 is an

elevation, and Fig. 25 the plan. *a* is a cast-iron carriage, bolted through the ship's side, and supporting the hook *d* by a pin or pivot at *b*; *d e* a lever turning upon a centre *f*, the end *d* being formed into a hook, which clasps the upper end of the bolt *b*, the lever being retained in the position shown in the plan, by a pin *g*; *h* is part of a chain forming the standing part of the shank-painter, and supported by the bolt *b*. To the other end of the chain is spliced the *running* part of the shank-painter, which passes round the shank of the anchor, and is made fast to a timber-head. When it is required to let go the shank-painter, an iron bar is inserted into the end *e* of the lever *d e*, which is made hollow for the purpose, and the pin *g* being withdrawn, the lever is turned round its centre until the bolt is released from the hook *d*, when it falls, and the chain end of the shank-painter slips off.

24.



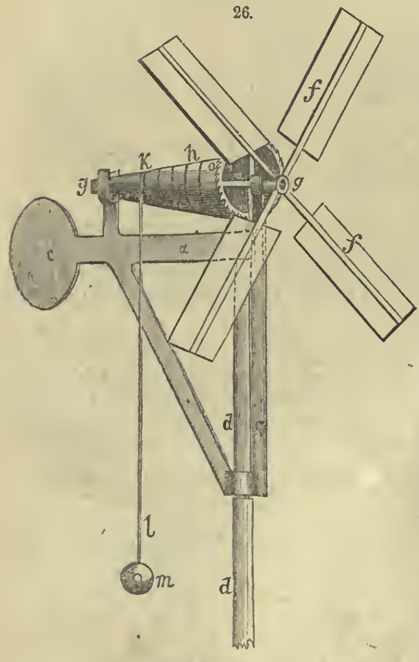
25.



ANGICA-WOOD. See Woods, *Varieties of.*

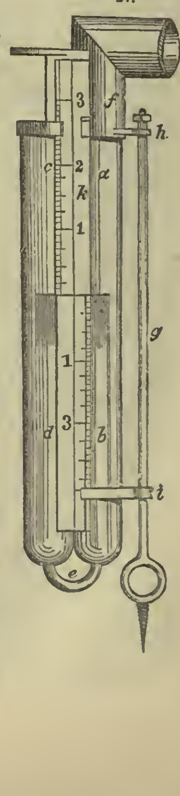
ANEMOMETER. An instrument for measuring the strength or velocity of the wind. Among various machines which have been constructed for this purpose, the following one has been found to answer very well. It consists of an open frame *a c*, supported by a shaft *d*, upon which it turns by the action of the wind upon the vane *e*. *f f* are sails, fixed to one end of the axis *g*, and disposed to be influenced by the wind in the usual manner. Upon this axis is also fixed a conical barrel of wood *h k*, on the smaller end of which *k* is attached a line *l*, with a weight appended to it. The wind acting upon the sails, causes the barrel to revolve, and the line to be wound up on its superficies. To prevent any retrograde motion, a ratchet wheel *o* is fixed to the base or larger end of the cone, having a clicker falling into the notches as it revolves. It is evident that the power of the weight will continually increase as the line advances towards the base of the cone, as the weight acts at a greater distance from the axis or fulcrum; consequently, the variable force of the wind may be readily ascertained by fixing the line at the smallest end, and marking the barrel with spiral lines, as taken up by the coiling of the rope round its superficies, placing also between the lines numerals to denote the force of the wind, which may be calculated with tolerable precision upon the principles of the lever. The diameter of the cone should be such in comparison with its smallest end, that the force of the strongest wind should have scarcely sufficient force to bring the line on to the base of the cone.

26.



Although the instrument described above gives an accurate idea of the comparative force of the wind at different times, it does not point out the actual force exerted on a given surface, nor can observations made with one instrument in a particular place, be compared with observations made by another instrument elsewhere. It is also cumbersome, and not portable. In the *Philosophical Transactions* for 1775, Dr. Lind gives a description of a very ingenious portable wind gauge, which indicates the actual force of the wind by the column of water which it will support. This instrument consists of two glass tubes *a b*, *c d*, which should not be less than 8 or 9 inches long, the bore of each being about four-tenths of an inch in diameter, and connected together by a small bent glass tube *e*, of about only one-ninth of an inch bore, to check the undulations of the water caused by a sudden gust of wind. On the upper end of the tube *a b* is fitted a thin metal tube *f*, which is bent at right angles, and has its mouth open to receive the wind blowing into it horizontally. The two branches of the tube are at liberty to turn round a steel spindle *g*, which passes through two slips of brass *h i* near the top and bottom of the instrument. The spindle is fixed into a block of wood by a screw in its bottom. When the instrument is used, a quantity of water is poured in until the tubes are about half full, and the instrument being then held perpendicularly, with its mouth exposed to the wind, the water will be depressed in the tube *a b*, and proportionably elevated in the tube *c d*; and the distance between the surfaces in the two tubes measured by a sliding scale of inches, and parts *k* attached to the instrument, will be the height of a column of water which the wind is capable of sustaining at that time; and as a cubic foot of water

27.

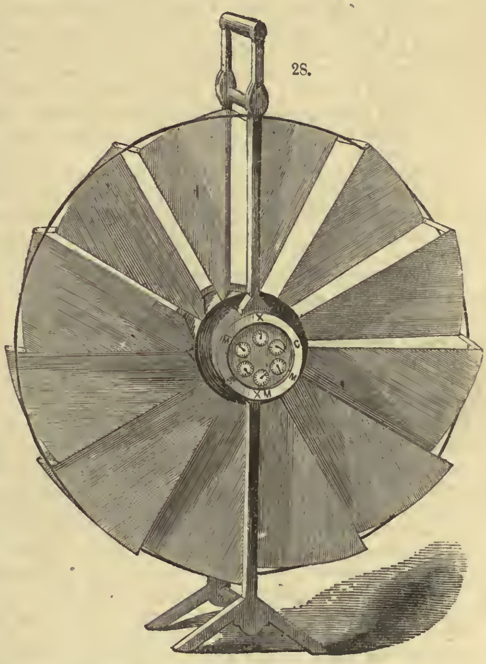


weighs 1000 ounces, or 62½ pounds nearly, the twelfth part of which is 5 5-24 pounds; therefore every inch the surface of the water is raised, the force of the wind will be equal to so many times 5 5-24 pounds on the square foot. This instrument shows the *force*, but not the *velocity*, of the wind; but as the force is as the square of the velocity, if the velocity due to a given force be ascertained, a table of the velocities corresponding to each inch the water is elevated, may be calculated and engraved upon the scale of equal parts. The table at the right, showing the corresponding height of water, velocity of the wind, and the force exerted upon a square foot of surface, has been calculated from some experiments made by Dr. Hutton.

Height of Water. Inches.	Force of Wind. lbs.	Velocity per Hour. Miles.
¼	1.3	18
½	2.6	25.6
1	5.2	36
2	10.4	50
3	15.6	62
4	20.8	76
5	26.	80.4
6	31.25	88
7	36.5	95.2
8	41.7	101.6
9	46.9	108
10	52.1	113.6
11	57.3	119.2
12	62.5	124.

BIRAM'S ANEMOMETER, (Fig. 28,) is designed to register the current of air in mines. In the recent report of the Committee appointed by the British House of Commons, for inquiring into the causes of accidents in coal mines, the adoption of some mode of measurement and registry, is strongly recommended. In this country the same degree of necessity for such precautions has not yet been reached, because our mines of bituminous coal are mostly shallow, and yield comparatively little of the combustible gases. In order to displace by fresh air these poisonous gases, as also the smoke of gunpowder, of lamps, and the products of respiration, it is necessary to build a fire in one of the shafts of the mine, and to keep it up at all times; so that the draught of the furnace shall cause a movement of the stagnant air in the galleries.

28.



Biram's Anemometer registers these movements of the air by a combination of wheels with indices, similar to a gas meter. It is only 12 inches in diameter, and weighs about 2½ lbs. Any slackening of the furnace, or inattention in the furnace man, will be at once detected by the registry of this simple apparatus. The observer has only to record the position of the several indices at the first observation, and deduct the amount from their position at the second observation, to ascertain the velocity of the air which has passed during the interval; this multiplied into the area in feet of the passage where the instrument is placed, will show the number of cubic feet which have passed during the same period.

ANEMOSCOPE, a machine that shows the course or direction of the wind.

Of late years instruments have been introduced into observatories for tracing continuously the force and direction of winds; the most common are those by Dr. Whewell and Mr. Osler. In the machine as arranged by Dr. W., a windmill fly is constantly presented to the wind in whatever direction it may blow, and the fly of course revolves with greater or less rapidity according to the velocity of the current. An intermediate train of wheels set in motion by the fly, causes a pencil to descend over a fixed cylinder, leaving thereon a trace of variable length, according as the wind is more or less strong. 10,000 revolutions of the fly causes the pencil to descend only one-twentieth of an inch. The surface of the fixed cylinder is japanned white, and is divided into 16 or 32 equal parts by means of vertical lines, the intervening spaces corresponding to 16 or 32 points of the compass, and a mark left by the pencil upon one or more of these spaces, shows the direction of the wind. The pencil has two motions, the first from above downwards, and this increases in rapidity as the wind blows more strongly, and by the extent of its depression registers the whole amount of wind that has been blowing. The second motion depends on the changes in the direction of the wind; and the pencil and its frame being carried round by the vane, the direction is registered by this cross movement. In this arrangement therefore, the vane, the windmill fly, the intermediate train of wheels and the pencil, all obey the direction of the wind; while the cylinder which marks the points of the compass remains fixed, so that the pencil in descending and moving about with the wind, thus traces an irregular line on the cylinder. If the fly revolves in the simple proportion of the velocity of the wind, the length of line marked by the pencil is proportional to the space which would be described by a particle of air in a given direction in a given time, such as one day, taking into account the strength of the wind and the time for which it blows.

In Osler's Anemometer, the force and direction of the wind, and also the amount of rain are regis-

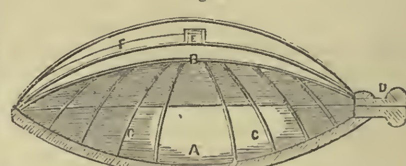
tered on a paper placed on a board moved by means of clock mechanism. The pressure is measured by a plate always directed so as to face the wind. Three pencils are used, of which one registers the pressure of the wind in pounds per square foot, another the direction of the wind, and the third the quantity of rain falling in a given time. Each paper registers during the 24 hours of the day, although it may be arranged for longer periods. The whole length of the paper is divided by vertical lines into 24 equal parts; at the top is a series of parallel lines, corresponding to the pressure in pounds per square foot; in the centre are lines corresponding to the cardinal points of the compass, and the lowe portion of the paper registers the quantity of rain.

The method by which the pressure plate is always made to face the wind is as follows: a set of vanes or sails revolve vertically in a plane at right angles to that of the pressure plate, and drive a cog wheel, which by rolling on a fixed cog circle, turns all the rest of the apparatus round until the vane are presented edgewise to the current, then the pressure plate being at right angles to the vanes is acted on with full effect. As the vanes turn in the direction of the wind, a spiral worm on the shaft raises or lowers a nut, from which hangs the arm carrying the middle pencil, which thus traces the direction of the wind on one of the long lines of the register paper if the wind be from one of the cardinal points, or a mark between these lines if it be blowing from intermediate points, such as N.N.W., N.W. &c. The rain after falling into a vessel on the roof flows into one of the two divisions of a gauge balanced on an axis and supported by a second balance. As the water accumulates this second balance begins to descend, and so raises the upright rod to which a lever is attached which causes the pencil to rise. When this quantity becomes equal to a certain depth of rain, or to a certain number of cubic inches on a foot square, the small gauge oversets, the water is discharged, and the other compartment of the gauge is brought under the pipe. The pencil then returns to its first position at the bottom of the paper, and begins to rise on the scale as the rain is collected. In a trace of this kind it will be seen that the more rapidly the rain falls, the sharper will be the angles formed by the trace of the pencil; but if the rain be slow and gradual, the elevating or diagonal lines will be drawn out to a considerable length.

ANEROID BAROMETER. The principle of the instrument is dependent upon the action of the atmospheric weight upon the exterior of an exhausted or partially exhausted case of thin metal, the top of which, being slightly flexible, is so contrived as to convey indications of the minutest changes in the atmospheric column to a graduated dial, upon which the readings are exhibited as in the ordinary wheel barometer.

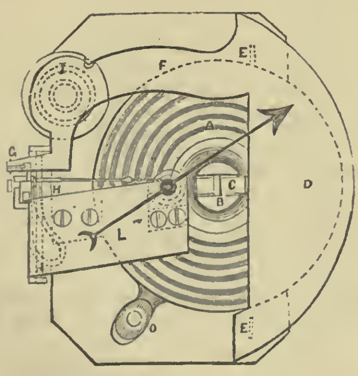
The original instrument of M. Conté bears a resemblance to a watch; it consists of a strong iron or brass box *a*, in the vertical section Fig. 29. To the edges of this box, a very thin and flexible steel cap *b* is fitted with great accuracy. *c c* are a series of springs acting between the bottom of the box and its flexible top, so as to press the latter up. A small cylinder is fitted at *d*, by which the case, when exhausted, may be hermetically closed. The dial is placed immediately over the top of the case, and is pierced in the centre for the passage of a central tube *e*, carring an index-needle *f*, the whole being surmounted by a concave glass. It is obvious that if the space enclosed by the case is exhausted, the flexible top or cap *b* being acted upon by the unbalanced pressure of the atmosphere, will fall, and compress the supporting springs *c*; and the converse takes place when any diminution in the atmospheric pressure occurs. By simple mechanism placed in the tube *e*, this movement of the cap may be communicated to the index-needle, which will thus register the variations in the columnar pressure. It is stated that the thermal changes of the atmosphere disturbed the action of the instrument, and eventually caused M. Conté to discard it as useless.

Fig. 29.

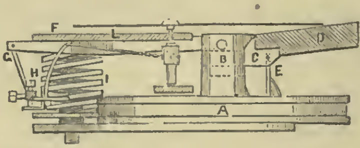


The objection of the want of any temperature compensation, M. Vidi has sought to remove in the Aneroid of the present day. One of the great features which were introduced at this time, was the cir

80.



81.



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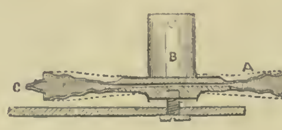


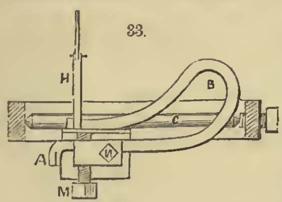
cular corrugation of the flexible diaphragm; and thus a larger and more available range of movement was obtained without danger of rupture. Fig. 30 is a half-size plan of the instrument as now made, under the superintendence of Mr. Dent; Fig 31 is a corresponding side elevation. The vacuum chamber

is represented at a; its top and bottom are formed of disks of thin circularly corrugated copper, held together by a circumferential strip of plain metal, as shown in the detail fig. 32, which is a vertical section of the chamber detached A strong brass stud b, is attached to the upper diaphragm of the chamber, having a slot on its end, through which a small projecting pin c, formed on the lever-plate a projects, the attachment being effected by a pin passed transversely through the slotted portion of the stud, immediately over the pin c. The plate d, which acts as a lever in communicating the movements of the diaphragm, rests upon two pillars e, carried by the supporting base-plate of the vacuum chamber, as fulcra. The projecting lever portion f conveys the movement by a joint at g, which is linked to a rocking spindle carrying the lever h, connected to the arbor of the index-needle by a fine chain which winds upon it, like the main-spring chain of a watch upon the spring box. In the interior of the vacuum chamber, a single helix is fixed upon the base-plate, so as to abut against the lower surface of the lever at i, and thus preserve the two diaphragms of the chamber from actual contact.

To set the instrument to indicate the same scale as the mercurial barometer, the arrangement given full size in Fig. 33 is adopted, to form the connection between the main lever and the index arbor. The link from the end of the main lever is joined to an eye at a, on a stud formed upon the end of a metal bow piece b, the contrary end of which is attached to the lever h, before described. The whole of these parts are carried by a nicely adjusted rocking spindle c, working on centres in the frame l. The office of this contrivance is to afford a means of adjustment for the index movement by the two screws $m\ n$, one of which elevates or depresses the eye a, whilst the other sets it in or out from the centre of the rocking spindle, to give more or less leverage, as may be required to suit the barometrical scale. The connection between the index arbor and the lever apparatus being by a flexible chain, its movement can act only in one direction in bringing round the index, and a fine hair spring is attached to give the return movement.

The tube by which the exhaustion is effected is at o. The process of exhausting, as specified by the inventor in connection with the original plan, is as follows. A little solder is placed round the aperture for the exhaust, in which a flat-headed pin is set, so open as to admit the air to pass. The diaphragm is compressed to its proper position by means of a board, and is then soldered to its box. The whole is afterwards placed under an air-pump receiver, having an air-tight stuffing-box, through which a rod, carrying the heated soldering-iron is passed. When the vacuum is obtained, the soldering-iron is pressed down to melt the solder round the peg, and close the opening.

33.



A simple mode of adjusting the instrument by a standard barometer is obtained by a screw-stud projecting through the back of the instrument, in connection with the reacting spring at i, the tension of which may thus be varied to the extent required. By a simple arrangement, the vacuum case is itself made to afford its own temperature correction, without the addition of a particle of mechanism. Previous to the exhaustion of the vacuum chamber, the top and bottom diaphragms are both perfectly horizontal; but when exhausted, they each take the curve shown in the section fig. 32, and the dotted lines represented as running nearly even with the corrugated surfaces indicate the position they will assume when a portion of gas is introduced to play the important part of a compensator for the disturbance to which the index would be liable from changes of temperature. The expansion of the contained gas, arising from the disturbing cause itself, counteracts the loss of elastic force produced by the same cause in the diaphragms and other parts of the machinery. The external atmosphere is continually endeavoring to press down the diaphragm, whilst the helix beneath the lever is as continually acting to keep it up. An increase in temperature expands the contained gas, which thus diminishes the effect of the external atmospheric pressure, and corrects the disturbance arising from the expansion of the various levers and connections, which would otherwise indicate upon the dial a greater amount of movement than is actually due to the atmospheric change.

ANGLE, in Geometry. If two lines drawn on a plane surface are so situated that they meet in a point, or would do so, if long enough, they form an opening which is called an angle. When one line meeting another makes the angles on both sides equal to each other, then these angles are each called a right angle, and in this case the one line is said to be perpendicular to the other. In the common language of workmen, the one line is said to be square with the other; and if the one line be horizontal, the perpendicular is said to be plumb to it. The arc which measures a right angle, is the quarter of the whole circumference, or is a quadrant, and contains 90 degrees; any angle measured by an arc less than this, is acute, (sharp,) and if by an arc greater than a quadrant, obtuse, (blunt.)

ANIMAL KINGDOM, materials from—used in the mechanical and ornamental arts.

Porcelanous and nacreous shells, bones, etc.—The hard solid substances derived from the Animal Kingdom, are parts of the external or internal skeletons, as shells and bones; or of the instruments of sustenance and defence, as horns, hoofs, nails, claws, and teeth: these, together with the various coverings of animals, whether hair, feathers, or scales, are alike composed of animal and earthy matters, almost exclusively albumen, gelatine, and lime, combined in various proportions, and with a structure more or less interspersed with animal fibre. Many of these are either formed by the deposition of successive annual layers, or they are altogether yearly renewed.

A brief consideration of the chemical difference between their component parts, and of their respective proportions, in such as are used in the arts, will show the reasons for their various characters, and different treatment with tools.

Albumen, the principal ingredient of these animal substances, and which exists in the purest form in the white of eggs, is hardened by a degree of heat less than the boiling temperature of water, and is insoluble in the same. Gelatine, of which jelly and glue are different examples, is softened by heat, and rendered fluid by the addition of water: both are easily cut and scraped, in all their various stages from

soft to hard, and during this change they contract very materially, but without entirely losing their elasticity.

The earthy matters of the animal solids, principally the phosphate and carbonate of lime, are widely different from the foregoing, and also from the substances of the woods and metals. They are inelastic, and often crystalline, and therefore incapable of being cut into shreds or shavings; as when they are divided, they become smaller fragments or particles which are always angular: they are comparatively uninfluenced by water or small changes of temperature, and are incapable of contraction.

When the earthy and crystalline structures prevail, the animal substances are harsh, incapable of absorbing moisture, or of alteration of size or form; when the animal and fibrous characters prevail, they are easily cut, and they absorb moisture, soften, and swell. Enamel of teeth, the hardest of the class, contains from 2 to 3½ per cent of animal matter, (Berzelius.) Porcelanous shells are nearly similar. Nacreous shells, 24 per cent, (Hatchett.) Ivory, 24 per cent, (Ure;) 25 per cent, (Merat Guillot.) Bone, 33 per cent, (Berzelius.) Horn, is coagulated albumen and lime, with ½ per cent of phosphate of lime, (Ure.) Tortoiseshell is nearly the same as horn. The horn of the buck and hart are intermediate between bone and ordinary horn, (Ure.)

In some of the shells, the quantity of animal matter is so small, and the lime is in so hard and compact a form, that they are very brittle, partially translucent, generally they have smooth surfaces, and are incapable of being cut with a knife or tools; such shells are called *porcelanous*, from their resemblance to porcelain, they include most of the univalve shells, such as the whelks, limpets, and cowries. Most of these can only be worked upon after the manner of the lapidary, with emery and other gritty matters harder than themselves, by which means they are cut and polished, as will be explained in speaking of that art; by analysis, porcelanous shells are considered closely to agree with the enamel of the teeth.

The nacreous shells, thus named from *nacre*, the French for mother-of-pearl, are most commonly known in the shells of the pearl-bearing oyster of the Indian Seas, (*Ostræa margaritifera*,) but they include the generality of the bivalve shells, as the various oysters, muscles, &c.; within they are smooth and iridescent, without they have a rough coat or epidermis.

These kinds contain a larger proportion of animal matter, which is considered to be arranged in alternate layers with the carbonate of lime; and as these shells also are impenetrable to water, they neither shrink nor swell. The pearl shells are less frangible and hard than the porcelanous shells, and they admit of being sawn, scraped, and filed, with ordinary tools; but they are harsh, scratchy, and disagreeble under the operation.

The beautiful iridescent appearance of the pearl shells is attributed to their laminated structure, which disposes their surfaces in minute furrows, that decompose and reflect the light; and owing to this lamellar structure, they also admit of being split into leaves, for the handles of knives, counters, and the purposes of inlaying. As the pieces are very apt to follow, and even to exceed the curvature of the surface, splitting is not much resorted to, but the different parts of the shell are selected to suit the several purposes as nearly as possible; and the excess of thickness is removed upon the grindstone in preference to risking the loss of both parts in the attempt to split them.

The usual course in preparing the rough pearl shell for the arts, is to cut out the square and angular pieces with the ordinary brass-back saw, and the circular pieces, such as those for buttons, with the annular or crown saw, fixed upon a lathe mandrel. The sides of the pieces are then ground flat upon a wet grindstone, the edge of which is turned with several grooves, as the ridges are considered to cut more quickly than the entire surface, from becoming less clogged with the particles ground off. The pieces are finished upon the flat side of the stone, and are then ready for inlaying, engraving, and polishing, according to the purposes for which they are intended. Cylindrical pieces are cut out of the thick part of the shell, near the joint or hinge, and rounded upon the grindstone, ready for the lathe, in which they may be turned with the ordinary tools used for ivory and the hard woods.

The following are considered by an experienced dealer to be the respective qualities of the pearl shells. The Chinese, from Manilla, are the best; they are fine, large, and very brilliant, with yellow edges. Singapore, fine large shells, dead-white. Bombay, a common article. Valparaiso, also common, with jet-black edges. South Sea pearl shells, common, with white edges.

The very beautiful dark-green pearl shells, are known as ear-shells or sea-ears; they are unlike the others in form, being more concave, and with small holes around the margin, and are the coverings of the *Haliotis*, found in the Californian, South African, and East Indian Seas. Cameos are cut in the conch shell, *Strombus Gigas*, of the southern coast of America, and the West Indian Islands.

Mr. E. H. Bond states that he has seen the Chinese work the largest of known shells, the *Chama Gigas* of Linnæus, the *Tridacna Gigas* of Lamarck, into snuff-bottles, tops of walking-sticks, bangles, (a kind of bracelet,) and similar articles, some of which he possesses. The shell is a bivalve and not nacreous, generally white, sometimes pale blue; it may be beautifully polished, and is less readily scratched than mother-of-pearl; its localities are the Indian Seas, New Holland and the Red Sea, but the largest are obtained from Sumatra, one pair from whence, described in Sir Joseph Banks' MSS. Library, is said to weigh, the one valve 285, the other 222 pounds, but the more usual weight is about 100 pounds each valve. Mr. Bond considers the useful portions of the shell, already prepared, might be obtained from China.

In the bones of animals, the earthy and animal matters are more nearly balanced; they are therefore less brittle than the shells, but prior to being used they require the oil with which they are largely impregnated to be extracted by boiling them in water, and bleaching them in the sun, or otherwise. This process of boiling, in place of softening, robs them of part of their gelatine, and therefore of part of their elasticity and contractibility likewise they become more brittle, and having a fibrous structure, they break in splinters.

The forms of the bones are altogether unfavorable to their extensive or ornamental employment; most of them are very thin and curved, contain large cellular cavities for marrow are are interspersed with vessels that are visible after they are worked up into brushes, spoons, and articles of common

turnery. The buttock and shin bones of the ox and calf, are almost the only kinds used. To whiten the finished works, they are soaked in turpentine for a day, boiled in water for about an hour, and then polished with whiting and water.

Bone is far less disagreeable under the tools than the pearl shell, but it is nevertheless hard, harsh, and chalky; the screws cut on bone are imperfect and soon injured. It is harder, often whiter, but much less pleasant to work than ivory, which beautiful material will be treated of separately.

Horn.—In the English language we have only one word to express two quite different substances; namely, the branched bony horns of the stag genus, and the simple laminated horns of the ox genus, and other kindred genera.

The bony horns are called in the French *bois*, from their likeness to the branch of a tree; they are annually renewed.

The other sort of horn, to which the French appropriate the term *corne*, and which is the subject of our present inquiry, is found on the ox, the antelope, the goat, and sheep kinds.

These two kinds will be considered separately.

The stag-horn closely resembles the ordinary solid bones, both in its chemical characters, and also in structure, as it is spongy and cellular in its central parts. The horn is sawn into pieces, filed to the required shapes, and used without any further preparation, the natural rough exterior of the horn being left in the original state; its appearance is neat and ornamental, and from its uneven surface is very suitable for the handles of knives, and other instruments requiring to be held with a firm grasp.

When short pieces of stag-horn are used entire, as for the handles of table-knives, the hollow cellular part is concealed by the addition of the metal cap, and those parts of the white internal substance, which are necessarily exposed, are browned with a hot iron, or the flame of a blowpipe, so as nearly to match the other parts.

The horns of the ox tribe are deposited in annual layers upon the bony cores that project from the foreheads of the animals; whence it results, that the general form of the horn, (neglecting its curvature,) is conical, the portion beyond the core is solid, and the other extremity tapers off so as to terminate at the base in a single plate, or extremely thin edge.

Horn consists almost entirely of animal matter, chiefly membranous—namely, coagulated albumen with a little gelatine, and an inconsiderable portion of phosphate of lime; had the horns much more earth they would be brittle like bones, had they much more gelatine they would be soluble like jelly or glue; as they are constituted, the quantity of gelatine is only sufficient to allow them to be considerably softened by a degree of heat not exceeding that of melted lead, after which they may be cut open with knives or shears, flattened into plates, divided into leaves, and struck between dies like metal. Their gelatine serves as a natural solder, so that neighboring surfaces, when perfectly free from greasy matter, may be permanently joined together by moisture, heat, and pressure: the union becomes perfect, but horn being a cheap material, the process of joining it is seldom practised.

The straight conical horn of the rhinoceros is also occasionally used; it is solid, and formed as of a group of hairs cemented together: the transverse section of the upper part of the horn exhibits small dots. The horns of the chamois and antelope, and those of some other animals, are generally looked upon as natural curiosities, and are only polished exteriorly, without any strictly manufacturing process being applied to them.

The first step in operating upon horn is the separation of the bony core, which is effected by macerating the horns in water for about a month, when, from the putrefaction of the intermediate membrane, the core may be readily detached; this is not thrown away, but burnt to constitute the bone earth used for the cupels for assaying gold and silver.

The solid portion or tip of the horn is usually sawn off, and the remainder, if not cut into short lengths, is softened by immersion for half an hour in boiling water; it is then held in the flame of a coal or wood fire, until it acquires nearly the heat of melted lead, when it becomes exceedingly soft, after which it is slit up the side with a strong pointed knife, and opened out by means of two pairs of pincers applied to the edges of the slit; and lastly, the "*flats*" are inserted between iron plates previously heated and greased, which are squeezed tight in a kind of horizontal frame or press by means of wedges; wooden boards may be used.

For general purposes, as for combs, the pressure should be moderate, otherwise, in the language of the workman, it *breaks the grain*, or divides the laminæ, and causes the points of the teeth to split; but great pressure is purposely used in the manufacture of the leaves for lanterns, which are afterwards completely separated with a round-pointed knife, scraped, and polished. The heat and pressure when applied to the light-colored horn render it almost transparent.

An improved mode of "opening horn" was invented by Mr. J. James, by which the risk of its being scorched or frizzled over the open fire is entirely removed; he employs a solid block of iron with a conical hole, and an iron conical plug: these are heated over a stove to the temperature of melted lead, and the horn, after having been divided lengthwise with a saw or knife, is inserted in the hole, the plug is gradually driven in with a mallet, and in the space of about a minute the horn is softened and ready for being opened in the usual manner.

In making drinking-horns, and some few other turned works, the material is cut to the appropriate length, brought to the circular form, and allowed to cool in the mould; the process is similar to that just described, although the old methods of the open fire and wooden cones are commonly used. The horn is then fixed in the lathe by its larger end, and turned on its inner and outer surface, and the groove, or *chime* for the bottom, is cut with an appropriate tool. A thin plate, previously cut out of a flat piece of horn with a crown-saw, is dropped into the horn, and forced into the groove, after the horn has been sufficiently heated before the fire to allow the necessary expansion; in cooling, the contraction fixes the bottom water-tight.

As an illustration of the peculiar properties of horn, and a mode of its employment in the lathe, may be mentioned the expanding snake: this toy is well known to consist of a conical piece of horn, the

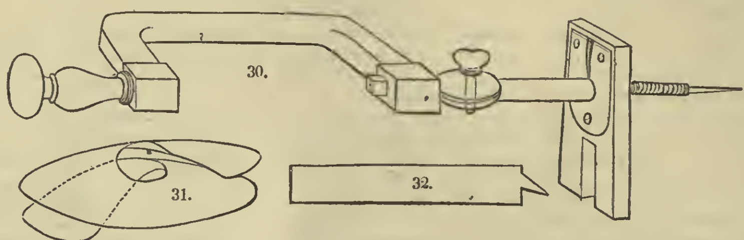
one end of which is carved to represent the head, and the remainder is cut into a single spiral shred, so as to admit of great expansion, in imitation of the body of the reptile. I find the elastic portion of the one before me to measure, when compressed, barely one inch and a quarter in length, and that it expands to upwards of three feet and a half, or thirty-five times: no mean proof of the elasticity of the material.

In making this trifle, the material is first turned to a conical form, after which a hole of about one-eighth or one-sixth of an inch diameter, is pierced from the tail almost through the head; the horn is then soaked for about two days in cold water to soften it, and the spiral incision or screw is made at one single cut, by means of a tool extending from the centre to the circumference; the cutter is not required to be very thin, as the shaving will bend away to make room for the same. One of the three following modes of proceeding is recommended in the *Manuel du Tourneur.*

First, by the employment of a sliding rest, adapted to cutting screws, by which the tool is *traversed,* or guided mechanically along the horn during the rotation of the mandrel of the lathe; and to prevent the fracture of the toy during its construction, a stick of wood, with a button on the end of it, is put up the aperture, to receive and support the spiral as it is produced.

Another method is by the employment of a lathe with a *traversing* or screw-cutting mandrel, upon which latter the horn is fixed, the tool being kept *stationary* in the slide-rest. Both methods require expensive apparatus, the principles of which will be explained in the article on screw-cutting tools.

The third plan is extremely simple; and appears, on inspection, to have been the one pursued in this instance: it is ascribed to the German toy-makers. The horn is prepared as before, but the lathe and slide-rest give way to the ordinary carpenter's brace, which carries the piece of horn, as in Fig. 30. A



small tool is fixed in the vice or bench; it consists of a piece of wood, to which is screwed a hardened steel plate about one-twelfth of an inch thick; it has a hole equal to the diameter of that in the horn, for the passage of the supporting wire; the plate is divided radially, the one edge is sharpened very keenly, and bent so much in advance of the other, that their *difference* of level or agreement, shall be equal to the intended *thickness* of the continuous shaving of the body of the snake, and therefore the projecting edge assimilates to the mouth of a plane: the last processes, in every case, being to carve the head and to attach a little piece for the end of the tail.

It is necessary the coils of the snake should be of a conical form, or dished, as in Fig. 31, instead of being quite flat, as it increases the strength of the toy; this is accomplished by making the cutting edge of the tool *oblique* to the axis of the snake; Fig. 32 shows the tool for the lathe. The several details are too simple to require further explanation.

The handles for knives, razors, and other works moulded in horn, are thus made: the horn is first cut into appropriate pieces with the saw, and when heated these are pared with a knife or spokeshave, to the general form and size required; in this state horn works as easily as a piece of deal: after having been pared, the pieces are pressed into moulds.

An idea of the moulds will be conveyed by imagining two dies, or pieces of metal, parallel on their outer surfaces, and with a cavity sunk entirely in the one, or partly in each, according to circumstances: the cavities made either straight, curved, twisted, rounded, bevelled, or engraved with any particular device, according to the pattern of the work to be produced.

The pressure is applied to the dies, by enclosing them in a kind of clamp, made like a very strong pair of nut-crackers, but with a powerful screw at the end opposite to the joint; the mould, dies, and horn, are dipped into boiling water for a few minutes, and then screwed as fast as possible immediately on removal from the same, and in about twenty minutes the work is ready for finishing; some handles are made of two pieces joined together.

On referring to French authorities, I find it stated that horn, steeped for a week in a liquor, the active ingredient of which is caustic fixed alkali, becomes so soft that it may be easily moulded into any required shape. Horn shavings subjected to the same process become semi-gelatinous, and may be pressed in a mould in the form of snuff-boxes and other articles. Horn, however, so treated, becomes hard and very brittle, probably in consequence of its laminated structure being obliterated by the joint action of the alkali and strong pressure.

Horn is easily dyed by boiling it in infusions of various colored ingredients, as we see in the horn lanterns made in China. In Europe it is chiefly colored of a rich red-brown, to imitate tortoiseshell, for combs and inlaid-work. The usual mode of effecting this is to mix together pearlash, quicklime, and litharge, with a sufficient quantity of water and a little pounded dragon's blood, and boil them together for half an hour. The compound is then to be applied hot on the parts that are required to be colored, and is to remain on the surface till the color has struck; on those parts where a deeper tinge is required, the composition is to be applied a second time. This process is nearly the same as that employed for giving a brown or black color to white hair; and depends on the combination of the sulphur, (which is

an essential ingredient in albumen,) with the lead dissolved in the alkali, and thus introduced into the substance of the horn. The horn which is naturally black is less brittle than that which is so stained.

Tortoiseshell comes next under consideration. The animal which produces this beautiful substance is a marine tortoise, called the *Testudo imbricata*, or hawk's-bill turtle.

The usual size of the full-grown animal is about a yard long and three quarters of a yard wide; its covering consists of thirteen principal plates, five down the centre of the back, and four on each side, and in a tortoise of the above size, the largest, or main-plates, weigh about nine ounces, and measure about thirteen by eight inches, and one quarter of an inch thick at the central parts; but they are thinned away at the edges where they overlap, owing to the deposition of the substance of the shell in annual layers, each extending beyond the previous one. Very rarely, the shells are three-eighths thick and proportionately heavy. Others are very thin, and appear to consist of only one single layer; this is supposed to occur when the animal loses a plate by accident, or that it is stripped and thrown back again into the sea whilst alive; such shells are usually very light-colored and are called "yellow belly." There are also twenty-five small pieces of shell which envelop the edge of the animal, but these can only be applied to very small purposes.

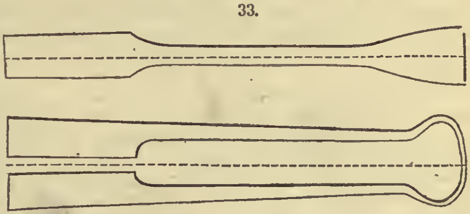
Some of the tortoiseshell is of very dark-brown tints running into black, and interspersed with light gold-colored dashes and marks, these are considered the best; others are lighter, even to pale red-browns, yellow, and white: the last are not valued, the yellow are used for covering the works of musical snuff-boxes, and the light red and brown shells are manufactured into ladies' combs, for exportation to Spain, where they obtain double the price of those made of the darker colored tortoiseshell. The shell of the turtle is also used, but it has not the transparent character of the foregoing; the colors are lighter, less beautifully marked, and it is little valued.

The treatment of tortoiseshell is essentially the same as that of horn, but on account of its very much greater expense, it is economized so far as possible. Before the shells are worked they are often dipped in boiling water to *temper* them; three or four minutes commonly suffice, but they require a longer period when they are either thicker or more brittle than usual: excess of boiling spoils the colors of the shells, renders them darker, and covers the outside with an opaque white film. Others, flatten and temper the shells with hot irons, such as are used by laundresses: the shell is continually dipped in cold water to prevent its being scorched; but as a general rule the less tortoiseshell is subjected to heat, or to being pulled about, the better, as from its apparent *want of grain* or fibre, it becomes in consequence very brittle.

Many of the works in tortoiseshell are made, partly by cutting them out of the shell, and partly by joining or adhesion, called by the French *souder*. Thus in the Manuel du Tourneur, the artist is directed to form the ring of tortoiseshell for the rebate of a box, by cutting out a long narrow slip of the shell; the ends are then to be filed with a clean rough file to thin feather edges, to the extent of three quarters of an inch of their length, the one on the upper and the other on the lower surface, to constitute the lap or joint; the slip is dipped into boiling water, and when softened it is bent into an oval form with the intended joint on the flat side, the ends are held in firm and accurate contact with the finger and thumb, and the piece is dipped into cold water to make it retain the form.

A pair of tongs is required, such as those in Fig. 33, with flat ends measuring about one inch wide and three or four long, and that spring open when left to themselves, but fit perfectly close and even, when compressed; these are made warm. In the mean time the ends of the ring are sprung asunder sidewise, to bring the *scarfs* or parts to be joined to the inner and outer surfaces respectively, that they may be retouched with the file to remove any small portion of grease which may have been accidentally picked up, and the joint is restored to its proper position. A piece of clean linen is then soaked in clean water, squeezed dry with the fingers, folded in ten to twenty thicknesses, to about the size of one and a half inch wide, and three or four long; the ends are now folded together, placed on each side the joint, the whole is inserted between the tongs, and fixed moderately tight in the jaws of an ordinary vice. The softening and consequent adhesion of the shell, will be known by the flexibility of the ring when the loose part is wriggled about with the fingers; the work is either allowed to cool in the vice, or after a time is dipped into cold water.

33.



The success of the process will depend on three different circumstances; the parts to be joined must be entirely free from grease and dirt, on which account the surfaces should not be touched after being filed; the temperature of the tongs should be just sufficient to color writing-paper of a pale orange tint; and moisture or vapor must be present, apparently to liquefy the gelatine of the tortoiseshell at the surfaces of union.

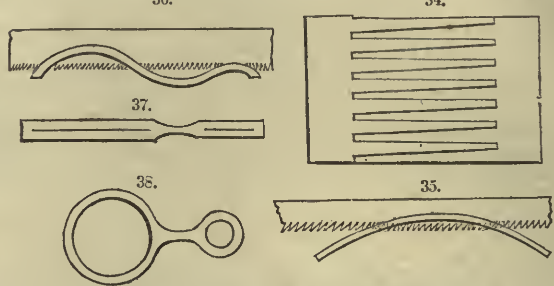
The ring, when cold, is pressed with the fingers into the circular form or even into an oval in the opposite direction, which would cause the ends of the joints to start, if the soldering were imperfectly performed; should this happen, the application of the moistened rag and heated tongs must be repeated until the result is perfect; the ring is made circular by warming it in boiling water, and gently forcing it on a wooden cone of small angle.

Another mode, the invention of an amateur, is also described; the strip of shell is chamfered off at the ends and bent round a piece of wood, a compress of linen in six or eight folds is put upon the joint, and the whole is tightly bound round with string, and immersed in boiling water for ten minutes. The contraction of the string, and the expansion of the wood, from being wetted, supply the needful pressure, and the process is said to be quite successful.

Moulding and soldering tortoiseshell, are also performed under water in various other ways for

example, in attaching the back of a large comb, to that piece which is formed into the teeth, the two parts are filed to correspond, they are surrounded by pieces of linen and inserted between metal moulds, connected at their extremities by metal screws and nuts; the interval between the halves of the mould, being occasionally curved to the sweep required in the comb. Sometimes also the outer faces of the mould are curved to the particular form of those combs in which the back is curled round, so as to form an angle with the teeth; the joint when properly done cannot be detected either by the want of transparency or polish at the part.

Considerable ingenuity is shown in turning to economical account the flexibility of tortoiseshell in its heated state; for example, the teeth of the larger description of combs are *parted*, or cut one out of the other with a thin frame-saw, when the shell equal in size to two combs with their teeth interlaced as in Fig. 34, is bent like an arch in the direction of the length of the teeth as in Fig. 35. The shell is then flattened, the points are separated with a narrow chisel or *pricker*, and the *two* combs are finished whilst flat, with coarse single-cut files, and triangular scrapers; and lastly they are warmed, and bent on the knee over a wooden mould, by means of a strap passed round the foot, in the manner a shoemaker fixes the shoe-last. Smaller combs of horn and tortoiseshell are parted whilst flat, by an ingenious machine, invented by Mr. Kelly. It has two chisel-formed cutters placed obliquely, so that every cut produces one tooth, the repetition of which completes the formation of the comb. Ivory and boxwood combs cannot be thus parted; they are cut in the old way, one tooth at a time, by various contrivances of double saws, as will be explained.

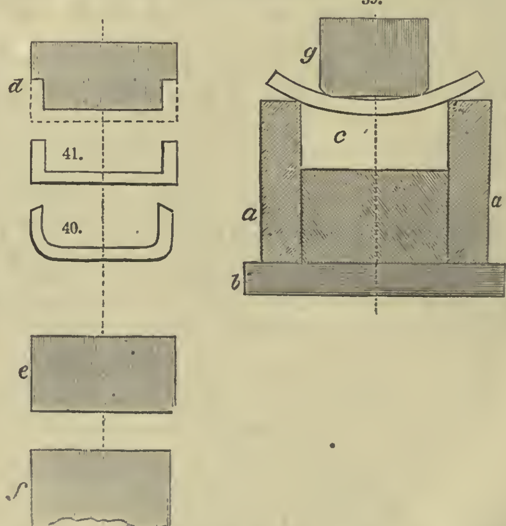

36. 37. 38. 34. 35.

In making the frames for eye-glasses and spectacles, the apertures for the glasses were formerly cut out to the circular form, with a tool something like a carpenter's centre-bit, or with a crown-saw in the lathe; the disks were in either case preserved, to be used for inlaying in the tops of boxes, and the outside of the frame was then shaped with saws and files. This required a piece of tortoiseshell of the entire size of the front of the spectacles, but a piece of a third that width is made to answer for inferior spectacles, as the *eyes* are *strained*, or *pulled*. A long narrow piece of the material is cut out, and two slits are made in it with a thin saw; the shell is then warmed, the apertures are pulled open, and fashioned upon a taper triblet of the appropriate shape: Figs. 36, 37, and 38, explain this method; the groove for the edge of the glass is cut with a small circular cutter, or sharp-edged saw, about three-eighths or half inch diameter, and the glass is sprung in when the frame is expanded by heat.

Tortoiseshell is also manufactured into boxes and a variety of moulded works, but the process calls for extensive preparations, and is not often followed by the amateur.

The construction of tortoiseshell boxes requires a copper, with a fireplace beneath; a trough with cold water; and a press and moulds. The former may be compared to the ordinary coining press, or to a strong rectangular frame, usually of wrought-iron, with a screw in the centre of the upper cross-piece; the base of the press is fitted into a square recess in the centre of the bench, fixed so firmly to the floor or wall, as to resist the efforts of two or three men at the end of a lever five or six feet long, whose entire force is sometimes required in tightening the mould. For the convenience of transferring the heavy press, from the hole in the bench to the hot or cold water, a crane, the centre of which is equally distant from the three, is added to the establishment.

The mould required for a round box consists of a thick wrought-iron ring *a a*, Fig. 39, turned interiorly to the diameter of the box; it stands loosely upon a plate *b*; it is accurately fitted with several pieces, commonly of brass, as *c* the bottom die, *d* the top die for a plain box, *e* a plain block for flat plates, and *f* a die engraved with any particular device to be impressed upon the work.



39.

In the *Manuel du Tourneur* the methods of making four different kinds of boxes are minutely given. Thus in the "*Boites à feuilles*," the best kind, in which the cover and bottom part are each made out of a single leaf of shell; the circular pieces are to be cut out of the shell as much larger than the size of the box, as the vertical height in addition to the diameter; so that a box of three inches diameter and one inch deep would require pieces of four and five inches respectively for the cover and bottom

The round plate of shell is first placed centrally over the edge of the ring, as in Fig. 39; it is slightly squeezed with the small round-edged block *g*, and the entire press is then lowered into the boiling water; in one quarter, or half an hour, it is transferred to the bench, and *g* is pressed entirely down, which bends the shell into the shape of a saucer, as at Fig. 40, without cutting or injuring the tortoiseshell, after which the press is cooled in the water-trough. The same processes are repeated with the die *d*, which has a rebate turned away to the thickness of the shell, and perfects the angle of the box to the section Fig. 41, ready for completion in the lathe; it is however safer to perform each of these processes at twice, with two boilings.

When the shell is insufficiently thick, two pieces are joined together, and should they from the nature of the shell be of irregular thickness, the thick and thin parts respectively are placed in contact; for such cases the dies *c e*, of a larger mould, are used. The piece *d* is adapted to boxes of various depths, or to the tops or bottoms respectively, by slipping loose rings upon it to contract the length of its smaller part.

When the box is required to have a device, an engraved die *f* is substituted in place of *c*. The same tools are also used for horn boxes, and for the embossed wooden boxes, but the latter process is mostly performed in the dry way, the warmth being supplied by heated plates, put above and below the two parts of the mould which are then compressed, and the whole is allowed to cool in the air.

The *Manuel* describes the construction of inferior boxes, "*Tabatières de morceaux*," in which small pieces of tortoiseshell with bevelled edges are carefully fitted together with the file and arranged along the bottom and up the sides of the mould; or else they are first pressed into a flat plate, and made into a box as a separate process; but the joints, from the manner in which they are made, can scarcely ever escape observation.

The "*Boites de très-petits morceaux*" are made of still smaller fragments, which are often cemented on a thin leaf of shell to ensure their better union; and lastly, the "*Boites de drogues*" are made of the fine dust and filings, which are passed through a sieve, and treated in other respects much in the same manner as the foregoing, but these boxes are quite opaque and brittle; a thin hoop of good tortoiseshell is sometimes inserted in the mould, to form the rebate of the box, which alone is then transparent; at other times, the shavings are mixed with mineral coloring matters, to imitate granite, lapis-lazuli, and other stones.

After the lapse of ten days or a fortnight, it sometimes happens the box shows a tendency to recover its primary form, that of a flat plate, and from being cylindrical on the edge, it becomes in a slight degree conical and larger without. After being again returned to the mould, boiled, and pressed, its figure is in general permanent.

This disposition is turned to useful account in restoring the fitting of a box that may have become loose, as by dipping the lower part, or the rebate, into warm water, it will expand and fill out the lid, but it requires care that it be not overdone.

The tortoiseshell boxes usually made, are those which are veneered upon a body or fabric of wood, for which purpose the plates are scraped and filed to a uniform thickness, and glued on much the same as veneers of wood; generally fine glue is the only cement used, but various compositions are resorted to by different manufacturers. To improve the appearance of the shell, and to conceal the glue and wood beneath, the back of the veneer is rubbed with a mixture of lampblack, vermilion, green, chrome, or white, in fish glue; the colors are applied over the entire surface, or partially to modify the effect, and thus prepared the veneers are glued upon the boxes.

In tortoiseshell works inlaid with mother-of-pearl and gold or silver plates or wire, the substances to be inlaid are first prepared; and for pearl shell a paper is pasted on a thin piece of pearl, the pattern is drawn thereupon, and the small pieces are cut out with a fine buhl-saw: gold and silver plates are sometimes also thus sawn out.

A plain mould similar to Fig. 39, but rectangular, and with plain dies, as *c* and *e*, is used; a few shavings of tortoiseshell are first placed on the piece *c*, to make a bed or cushion, then a piece of paper to prevent them from adhering to the thin leaf of tortoiseshell, which is next inserted in the mould. The small pieces of pearl shell, &c. to constitute the pattern, are then carefully arranged in their intended positions, and the top plate *e* is very carefully lowered into the mould above the pieces, so that it may not misplace any of them. The mould is then slid into the press, slightly squeezed, and plunged into the copper for an hour, carried to the bench and screwed moderately tight; the work is now examined to see that nothing is misplaced, it is returned to the caldron for a time, and the final squeeze is given by the entire force of three men, after which, whilst still under pressure, the whole is plunged into the cold water. The tablet is then fit to be smoothed and glued on the wooden box.

It will be readily conceived, that the force required depends upon the dimensions of the work; pieces of three or four inches square require all the appliances described; whereas the little ornaments upon razors and knives, may be pressed in with much slighter apparatus, such in fact as were previously described as being used in moulding them. In cutlery, a different method is generally resorted to, which applies equally well to ivory and pearl shell, substances which cannot be submitted to the softening and moulding processes employed for horn and tortoiseshell.

The cutlery works which are dotted all over with little studs of gold or silver, are drilled from thin pattern plates of brass or steel in which the series of holes have been carefully made; the drill or "*passer*" has an enlargement or stop, which, by encountering the surface of the pattern plate, prevents the point of the drill from penetrating beyond the assigned depth into the handle; the holes in the ivory or pearl shell are then filled with silver or gold wire, which is either filed and polished off level with the general surface, or allowed to project as little studs.

For small ornaments they use pattern plates or templets of hardened steel, pierced with the exact form. The cutting tool somewhat resembles an ordinary breast-drill eight or ten inches long, and like it, is used with the breast-plate and drill-bow; but the extremity of the tool is cleft, or made in two branches, which, left to themselves, spring open to the extent of an inch or more; each half of the tool

has a shoulder or stop, which bears upon the surface of the steel guard-plate, as in the drill, and a rectangular cutting part that protrudes through the shield-plate as far as the required depth of the recess, and is sharpened both at the end and side, or at the ends only.

When the elastic tool or "*spring-passer*" has been compressed so as to enter the guard-plate, it is put in motion, and flounders about in all directions, so far as it can expand, and routs or cuts out the shallow recess; the small ornaments are punched out, fixed by two rivets, and smoothed off; these processes are very expeditious, and produce accurate copies of the respective pattern-plates employed. The tortoiseshell, when unnecessarily thick for a single scale for a penknife, is sawn to serve for two; and the colors are brightened up by placing a piece of Dutch leaf beneath the same; they are finally polished on the various wheels used by the cutler. Tortoiseshell has been manufactured into hollow walking-sticks, and even bonnets.

Whalebone may be considered as a kind of horn; which latter substance it resembles perfectly, both in its chemical and principal physical properties; and is particularly interesting as forming the transition from horn to hair.

It is the substitute for teeth in the Greenland whale, and in the black southern whale; but is not found in any of the cetaceous animals that have teeth.

From the roof of the mouth hang down on each side the tongue about three hundred plates of whalebone, all the blades on one side being parallel to each other and at right angles to the jaw-bone. The average length of the middle blades is about nine feet, but they have occasionally occurred of the length of fourteen or fifteen feet.

The general color of whalebone is a dusky grayish black, intermixed with thin stripes or layers of a pale color, which are often almost white—very rarely the entire flake is milk-white.

The preparation of the whalebone for use is very simple. It is boiled in water for several hours, by which it becomes soft enough to be cut up while hot, in lengths of different dimensions, according to the use to which it is to be applied. Whalebone that has been boiled, and has become cold again, is harder and of a deeper color than at first; but the jet-black whalebone has been dyed, and by the usual processes it takes very bright and durable colors.

Whalebone is now principally used for the stretchers for umbrellas, and as a substitute for bristles in common brushes; it is also plaited into whips, and solid pieces of mixed shades are twisted for walking-sticks; but it does not admit of being soldered or joined together like tortoiseshell. Whalebone also furnishes a very neat and durable covering for pocket-telescopes. Narrow pieces of the material are grooved or made into ribs, by drawing them like wire through a corresponding aperture in a steel plate, after which they are wound round the tube, and "*tucked under*" the rings at the extremities. Broad flat strips of the party-colored whalebone, (the light portions of which absorb the green dye,) are also used: these are secured by narrow black bands which overlap the two edges, and other bands are wound around the ends also.

Ivory, the tusk or weapon of defence of the male elephant, and of which each animal has two, is placed by the chemists intermediately between bone and horn, and its mechanical characters corroborate the position. It is generally considered that the male elephant alone possesses tusks, commercially known as elephants' teeth, but this appears questionable, as by many the female is reported to have tusks likewise, but of smaller size, and some consider the latter produce the small solid tusks called "ball ivory," used for making billiard balls.

Ivory has less gelatine than bone; but as it leaves the animal in a state fit for use, without the necessity of removing any of its component parts for its purification, its elasticity and strength are not impaired by such abstraction. Ivory is not therefore so brittle as bone, neither does it splinter so much when broken, but its greater ultimate share of animal matter leaves it more sensible to change of form and size.

The shape of the tusk is highly favorable to its use, as it is in general solid for above half its length, and of circular or elliptical section; it is entirely free from the vessels or pores often met with in bone, and although distinctly fibrous, it cannot be torn up in filaments like horn, nor divided into thin flexible leaves, as for miniatures, otherwise than by the saw.

Its substance appears very dense, and without visible pores, as if beautifully cemented by oil or wax; and notwithstanding that it possesses so large a share of lime, it admits of being worked with exquisite smoothness, and is altogether devoid of the harsh, meager character of bone. It is in all respects the most suitable material for ornamental turning, as it is capable of receiving the most delicate lines and cutting, and the most slender proportions.

The general supply of ivory is obtained from the two present varieties of the animal, the Asiatic and the African: they are considered by physiologists to be distinct species, and to be unlike the extinct animal from which the Russians are said to obtain their supply of this substance; which, although described as *fossil* ivory, does not appear to have undergone the conversion commonly implied by the first part of the name, but to be as suitable to ordinary use as the ivory recently procured from the living species. An extract from the interesting account of "The Elephant of the Lena" is subjoined as a note.*

* "The Mammoth, or Elephant's bones and tusks, are found throughout Russia, and more particularly in Eastern Siberia and the Arctic marshes. The tusks are found in great quantities, and are collected for the sake of profit, being sold to the turners in the place of the living ivory of Africa, and the warmer parts of Asia, to which it is not at all inferior."

"Almost the whole of the Ivory-turner's work, made in Russia, is from the Siberian fossil ivory; and sometimes the tusks, having hitherto always been found in abundance, are exported from thence, being less in price than the recent. Although, for a long series of years, very many thousands have been annually obtained, yet they are still collected every year in great numbers on the banks of the larger rivers of the Russian empire, and more particularly those of farther Siberia."—The Naturalist's Library, 1836. Mammalia, vol. v., p. 133.

The Mammoth teeth are but rarely exposed for sale in this country. I only learn of two; the one weighed 186 pounds, was 10 feet long, of fine quality, and except the point, which was cracked, was cut into keys for pianofortes; the other also was large, but very much cracked and useless. Of the latter I have a specimen: the substance of the ivory between the

The hippopotamus, or river-horse, supplies the ivory used by the dentist, which is imported from the East Indies and Africa; the animal, in addition to twenty grinders, has twelve front teeth, the whole of which agree in substance with ivory, but not in their size or arrangement. The six in the upper jaw are small, and placed perpendicularly; in the lower jaw of the hippopotamus the two in the centre are long, horizontal, and straight, the two next are similar, but shorter; but the two external *semicircular* teeth are those so highly prized by the dentists on account of their superior size, and are those usually referred to when the "*sea-horse*" or hippopotamus tooth is spoken of, although the animal is in reality a quadruped inhabiting rivers and marshy places.

The circular hippopotamus teeth are covered exteriorly with a thick coat of enamel, which entirely resists steel tools, and will even strike fire with that metal; it is usually removed upon the grindstone* in order to arrive at the beautiful ivory within, which, owing to the peculiarity of its section, is better adapted to the construction of artificial teeth than the purposes of turning; the other teeth are tolerably round, and fit for the lathe.

The ivory of the hippopotamus is much harder than that of the elephant, and upwards of double the value; in color it is of a purer white, with a slight blue cast, and is almost free from grain. The parts rejected by the dentists are used for small carved and turned works.

In texture it seems almost intermediate between the proper ivory and the pearl shell; as when it is turned very thin, it has a slightly curdled, mottled, or damasked appearance, which is very beautiful; the general substance is quite transparent, but apparently interspersed with groups of opaque fibres, like some of the minerals of the chatoyant kind.

The teeth of the walrus, sometimes called the sea-cow, which hang perpendicularly from the upper jaw, are also used by the dentists; the outer part, or the true ivory, nearly resembles the above, but the oval centre has more the character of coarse bone; it is brown, and appears quite distinct. The long straight tusks of the sea-unicorn or narwal, which are spirally twisted, also yield ivory; but they are generally preserved as curiosities. These two kinds are principally obtained from the Hudson's Bay Company.

The masticating teeth of some of the large animals are occasionally used as ivory; those of the spermaceti whale are of a flattened oval section, and resemble ivory in substance; but they are dark-colored towards the centre, and surrounded by an oval band of white ivory: like that of the aquatic varieties generally, they are not much used.

The grinders of the elephant are occasionally worked; but their triple structure of plates of the hard enamel, of softer ivory, and of still softer cement, which do not unite in a perfect manner, render them uneven in texture. Owing to the hardness of the plates of enamel, the grinders are generally worked by the tools of the lapidary; they are but little used, and when divided into thin plates are disposed to separate, from change of atmosphere, the union of their respective parts being somewhat imperfect. They are made into small ornaments, knife-handles, boxes, &c.

The tusk of the elephant is, however, of far more importance than all these other kinds of ivory, and appears to have been extensively used by the Greeks and Romans. Amongst the former, Phidias was famous for his statues, thrones, and other works of embellishment, made in ivory combined with gold, an art described as the *Toreutic.* In reference to the construction of ivory statues, *Monsieur Quatremère de Quincy*, in his great work on ancient sculpture,† advances some curious speculations of their having been formed upon centres or cores of wood, covered with plates of ivory; and also that the ancients were enabled to procure larger elephants' teeth, or possessed the means of softening and flattening out those of ordinary size, from which to obtain the pieces presumed to have been thus employed.

These questionable suppositions, particularly the last, scarcely seemed called for, as solid blocks of ivory of the sizes commonly met with, would appear to be sufficient for the construction of colossal figures, in the mode ingeniously demonstrated by *M. de Quincy* in his plates 26 to 31. It is much to be regretted that none of these statues have descended to our times.

One of the constituent parts of ivory being animal matter, we should naturally expect it to be less durable than the inorganic materials, in which numerous fine specimens of ancient art still exist in great comparative perfection. Ivory appears not to suffer very rapid decay, in the lengthened deposition in the frozen earth of Siberia, nor when immersed in water; but various specimens in the British Museum, apparently less favorably situated, and in contact with the air, exhibit the effect of time, the ivory being decomposed and divided into flakes and pieces which exhibit its lamellar structure in a very satisfactory manner.

Elephants' teeth differ considerably in their size, weight, and appearance. The outsides of the African teeth run through all the transparent tints of light and deep orange, hazel, and brown, and some are almost black. Those from Asia are similar, although generally lighter, and frequently of a kind of opaque fawn, or stone-color; they have seldom the transparent character of the African teeth; and they commonly abound in cracks of inconsiderable depth, from which the others are comparatively free.

Some teeth are as long as from eight to ten feet, and as heavy as 150, rarely 180 lbs. each tooth; sometimes they are only as many inches long, and about one inch in diameter, and of the weight of five or six ounces, and even lighter; the teeth less than from 10 to 14 lbs. are called "scrivelloes." In section, the tusks are rarely quite circular, sometimes nearly elliptical, seldom exceeding the proportions of four to five, but commonly less exact than either of these forms; Figs. 43, 44, and 45, are accurately reduced from sections of teeth; the largest tusk the author has met with measured eight and a quarter inches the longest, and seven inches the shortest diameter of the irregular oval.

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cracks appears quite of the ordinary character, although the interstices are filled with a dry powder resembling chalk. Both teeth were *solid unto within six inches of the root.*

* The enamel of the hippopotamus is much thicker, but similar to that of the generality of masticating teeth, which is found upon analysis to agree very nearly with the hard porcelanous shells. The enamel is sometimes scaled off by driving a thin chisel between it and the ivory; and I learn, the flame of the blowpipe is likewise frequently used for the purpose of separating it. Several of the other teeth have enamel, but the semicircular tooth by far the most abundantly.

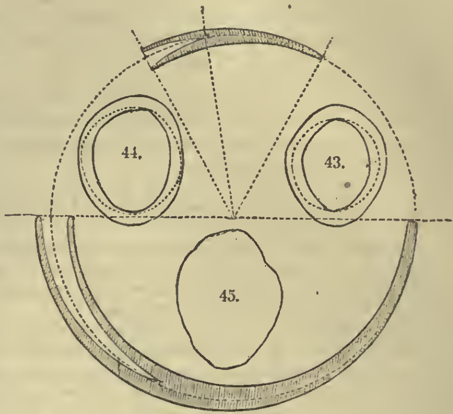
† Le Jupiter Olympien, ou l'Art de la Sculpture Antique. Paris, 1815.

The curvature of the teeth is sometimes as much as the half-circle, as in Fig. 46, and occasionally even so little or less than the sixth, as in Fig. 42; they are sometimes finely tapered off, especially in the African teeth, at other times their ends are very much worn away,—in rare instances, to the extent of a third of their apparent length, and generally more so on the one side of the centre than the other.

Other teeth end very abruptly, as if they had been broken and repointed before they left the head of the animal, in which they are generally inserted for about one-fourth their length.

The teeth are hollow about half-way up, and a speck, sometimes called the nerve, but in reality the apex of the successive hollows, is always visible throughout the length of the tusk to its extreme end, the tooth being formed by layers deposited on a vascular pulp after the manner of teeth generally.

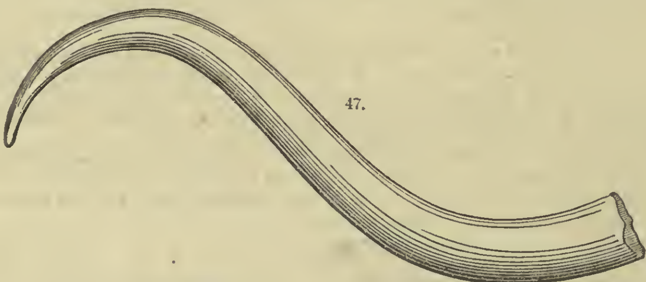
42.



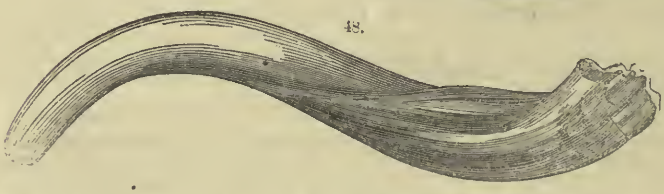
46.

The inner and outer surfaces of the teeth are in general tolerably parallel, and exteriorly they are curved in the one direction only, so as to lie nearly flat on the ground; but occasionally they are much curved in both directions, as represented in Figs. 47 and 48; the smaller is beautifully formed, and resembles in shape a handsome bullock's horn, the other is furrowed throughout its length, and appears the result of disease or injury.

The choice of ivory in the tooth is admitted by the most experienced to be a very uncertain matter; of course, for the purposes of turning, a solid cone would be the most economical figure, but as that form is not to be met with, we must be satisfied with the nearest approach that we can find to it, and select the tooth as nearly straight, solid, and round as possible, provided the other prognostics are equally favorable.



47.



48.

The rind should appear smooth and free from cracks, and if the heart should be visible at the tip, the more central it is the better; by the close inspection of the tip, from which the bark is always more or less worn away, it may be in general learned whether the tooth is coarse or fine in the grain, transparent or opaque, but the color of the exterior coat prevents a satisfactory judgment as to the tint or complexion of the ivory within.

After the most careful scrutiny on the outside of the tooth, however, the first cut is *always* one of a little anxious expectation, as the prognostics are far from certain, and before proceeding to describe the preparation of ivory, I will say a few words of its internal appearance when exposed by the saw.

The African ivory, when in the most perfect condition, should appear, when recently cut, of a mellow, warm, transparent tint, almost as if soaked in oil, and with very little appearance of grain or fibre; it is then called transparent or green ivory, from association with green timber; the oil dries up considerably by exposure, and leaves the material of a delicate, and generally permanent tint, a few shades darker than writing-paper.

The Asiatic ivory is of a more opaque dead-white character, apparently from containing less oil, and on being opened it more resembles the ultimate character of the African, but it is the more disposed of the two to become discolored or yellow. The African ivory is generally closer in texture, harder under the tools, and polishes better than the Asiatic, and its compactness also prevents it from so readily absorbing oil, or the coloring matter of stains when intentionally applied.

The rind is sometimes no more than about one-tenth of an inch in thickness, and nearly of the color

of the inner ivory, but occasionally it is of double that thickness, dark-colored, and partially stains the outer layers. As we do not find all specimens of the most perfect kind, we must be prepared to expect others, especially amongst the larger teeth, in which the grain is more apparent, but it generally dies away towards the centre of the tooth, the outside being the coarser; the regularity of the grain sometimes gives it the appearance of the engine-turning on a watch-case.

In some teeth, the central part will appear of the transparent character, the outer more nearly white; and the transparent teeth often exhibit, at the solid parts, white opaque patches, which are frequently of a long oval form. Amongst the white ivory, the teeth are often found to be marked in rings alternately light and dark colored; these are called "*ringy* or *cloudy*."

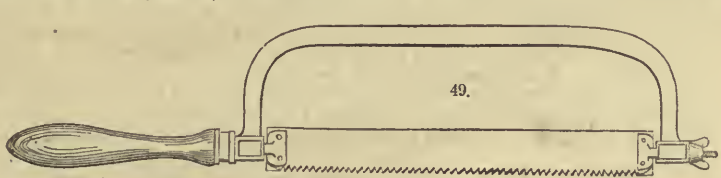
In those teeth in which there appears to be a deficiency of the animal oil, the intervals between the fibres occasionally assume the chalky character of bone, and are disposed to crumble under the tools unless they are very sharp; in this they resemble the softer parts of woods when worked with blunt tools; sometimes the ivory is not only coarse but dark or brown, and the two defects not unfrequently go together.

The cracks occasionally penetrate further than they appear to do when viewed from the outside, and more rarely a very considerable portion of the tooth is injured by a musket-ball, although the gold and silver bullets, said to be used by the Eastern potentates, are exceedingly scarce, or else transmuted into iron, of which metal they are commonly found, and less frequently of lead. The ball generally lacerates the part very much, and a new deposite of bony matter is made that fills up all the interstices, incrusts the hollow, and leaves a dotted mottled mass extending many inches each way from the ball, and which completely spoils that part for any ornamental purpose.

Preparation of Ivory.—On account of the great value of ivory it requires considerable judgment to be employed in its preparation, from three conditions observable in the form of the tusk; first, its being curved in the direction of its length; secondly, hollow for about half that extent, and gradually taper from the solid state to a thin feather edge at the root; and thirdly, elliptical or irregular in section. These three peculiarities give rise to as many separate considerations in cutting up the tooth with the requisite economy, as the only waste should be that arising from the passage of the thin blade of the saw: even the outside strips of the rind, called spills, are employed for the handles of penknives, and many other little objects; the scraps are burned in retorts for the manufacture of ivory black, employed for making ink for copperplate printers, and other uses; and the clean sawdust and shavings are sometimes used for making jelly.

The methods of dividing the tooth either into rectangular pieces, or those of circular figure required for turning, are alike in their early stages until the lathe is resorted to: I propose, therefore, to begin with the former. The ivory saw, Fig. 49, is stretched in a steel frame to keep it very tense; the blade generally measures from fifteen to thirty inches long, from one and a half to three inches wide, and about the fortieth of an inch thick; the teeth are rather coarse, namely, about five or six to the inch, and they are sloped a little forward, that is, between the angle of the common hand-saw tooth and the cross-cut saw. The instrument should be very sharp and but slightly set; it requires to be guided very correctly in entering, and with no more pressure than the weight of its own frame, and it is commonly lubricated with a little lard, tallow, or other solid fat.

49.



The cutler generally begins at the hollow, and having fixed that extremity parallel with the vice, with the curvature upwards, he saws off that piece which is too thin for his purpose, and then two or three parallel pieces to the lengths of some particular works, for which the thickness of the tooth at that part is the most suitable; he will then saw off one very wedge-form piece, and afterwards two or three more parallel blocks.

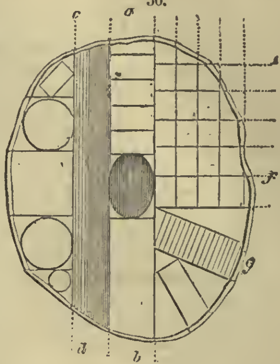
In setting out the length of every section, he is guided by the gradually increasing thickness of the tooth; having before him the patterns or gages of his various works, he will in all cases employ the hollow for the thickest work it will make. As the tooth approaches the solid form, the consideration upon this score gradually ceases, and then the blocks are cut off to any required measure, with only a general reference to the distribution of the *heel*, or the excess arising from the curved nature of the tooth, the cuts being in general directed, as nearly as may be, to the imaginary centre of curvature. The greatest waste occurs in cutting up very long pieces, owing to the difference between the straight line and the curve of the tooth, on which account the blocks are rarely cut more than five or six inches long, unless for some specific object.

In subdividing those blocks which are entirely solid, no great difficulty is experienced: in those which are nearly solid, as in Fig. 50, the first step is to cut a central slice just thick enough to avoid the hollow, unless the pieces *a b* are required to have some particular size; *c d* would serve for leaves for miniatures or veneering, and the remainder would be cut up of any required sizes, as sketched beyond *c d*. For square pieces of similar size, the block is cut into parallel slabs; for bevelled pieces, as the taper handles of knives and razors, the slabs are cut out wedge-form, the thick end of one against the thin end of the next, as at *e f:* these slabs are afterwards divided with parallel or inclined cuts, either with the frame or the circular saw.

In flat works, such as razor and knife handles, the broad surfaces, if cut radially, would show the edges of the rings or layers of the ivory; but cut parallel with the curve or as the tangent, the grain is

much less observable, and the ivory appears finer. In the keys for pianofortes this is particularly attended to; the finest broad keys are always cut upon the flat side of the oval, as at *f*, those upon the long diameter are cut into the narrow pieces called tails, (used between the black keys,) and the intermediate parts are cut obliquely as at *g*; this causes much waste.

50.



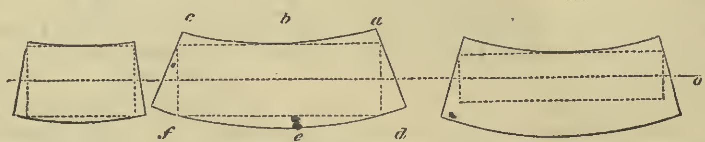
For such pieces as have large hollows, more management is necessary, as the thickness and curvatures of the material have to be jointly considered. When the hollows are thin, they are cut into squares or handles as large as the substance will allow; but on account of the circular section of the tooth, some of the pieces, if not all, must necessarily be angular or wedge-form; as regards pieces for the lathe, this is of little consequence.

In all cases the entire division of the block or ring should be determined upon, and carefully marked in pencil upon the end of the piece, before the saw is used.

When the tusk is cut up exclusively for turnery-work, the first cut is more generally made where the hollow terminates, which spot is ascertained by thrusting a small cane or a wire up the tooth; and every cut is directed as nearly as possible at right angles to the curve of the tusk, or to the centre of the circle, as before described. Unless the tooth is very far from circular, it is usual to prepare the principal quantity into cylinders or rings, as large as they will respectively hold, and the diagrams, Figs. 51, 52, and 53, are intended to explain the best mode of centreing the pieces, or placing them in the lathe.

If, as in preparing an ordinary block of wood, a circle were made at each end, and the work were chucked from the centres of the circles, as at *o*, Fig. 51, the largest cylinder that could be obtained would

53. 52. 51.



be that represented by the four sides of the dotted rectangle within that figure. Very much less waste would result from placing the centres so much nearer to the convex side, as to obtain the cylinder represented in Fig. 52, by allowing the waste to be equally divided between the points *a*, *c*, and *e*.

It is however more economical, to cut those teeth which are much curved into the shortest blocks, and the Fig. 53, which represents the proportions more commonly adopted, shows the small comparative degree of waste that would occur in a piece of half the length of the others, when centred in the most judicious manner.

The first process in preparing to rough-turn the block, is to fix it slenderly in the lathe between the prong chuck and the point of the popit-head, and its position is progressively altered by trifling blows upon either end, until when it revolves slowly, and the common rest or support for the tool is applied against the most prominent points *a*, *e*, and *c*, respectively, the vacancies or spaces opposite to each, at *d*, *b*, and *f*, shall be tolerably equal; so that, in fact, about a similar quantity may have to be turned away from the parts *a*, *e*, and *c*, for the production of the cylinder, represented by the dotted lines within the figure.

The centres having been thus found, they should be made a little deeper with a small drill; and then the one end of the block being fixed upon the prong chuck, the opposite extremity, supported by the centre, is turned for a short distance slightly conical, ready for fixing in a plain boxwood chuck, or a brass chuck lined with wood, to complete the rough preparation, unless indeed it is entirely performed upon the prong chuck.

With the decrease in length, less attention is requisite in the centreing, on account of the interference of the curvature of the tooth, and the pieces may be at once rasped to the circular form, and then chucked either in a hollow chuck, or else by cement or glue, against a plain flat surface.

When the blocks of ivory are long and much curved, a thin wedge-form plate may be sometimes sawn from the end, in preference to turning the whole into shavings; the end is turned cylindrically for a short distance, just avoiding to encroach on the lower angle of the block, and as soon as practicable, a parting tool is used for cutting a radial notch for the admission of the saw, which may be then employed in removing a thin taper slice. The process is at any rate scarcely attended with more trouble than turning the material into shavings, and thin pieces are retained for a future purpose, such in fact as these represented beyond the dotted lines at the ends of the figures.

The hollow pieces of ivory are treated much in the same manner as those which are solid, and into which latter condition they are sometimes temporarily changed, by rasping a piece of common wood, such as beech, to fit into the hollow, driving it in pretty securely, but so as not to endanger splitting the ivory; the work is then centred as recently explained, the chuck and centre being in this case received in the wood.

With the hollow pieces, the process of turning must be repeated on their inner surfaces, for which purpose a side cutting tool, with a long handle for a secure grasp, should be used: the tool should be held very firmly, so as to withstand the jerking intermittent nature of the cut, until the irregularities are reduced.

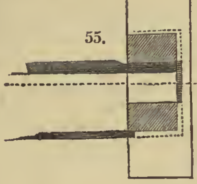
For this purpose the sliding-rest is very desirable, as the tool is then held perfectly fast without effort

on the part of the individual, and if the chucking be correctly done, the greatest possible economy of the material is attained; the hand tools succeed very well on the outer surface, as the rest or support upon which they are then placed is so close to every point of the exterior surface, that they may be held securely with less effort, although the sliding-rest is nevertheless desirable there also.

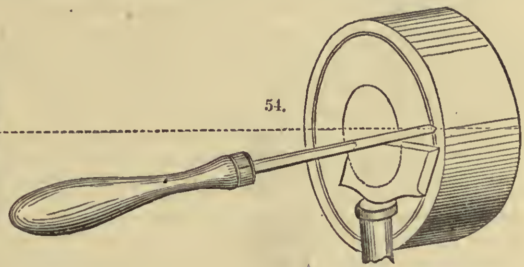
When the ivory hollow is thin, and far from circular, the material would be turned entirely into shavings, in attempting to produce a circular ring; the circular dotted lines in Figs. 43 and 44, are intended to explain this. Fig. 43 might be turned into an oval ring; but it is more usual to cut such irregular hollows into small square and round pieces, as explained.

When thin rings or short tubes are required, they are frequently cut one out of the other in the lathe, in preference to wasting the material in shavings; this is done with the parting tool, as in Fig. 54; an incision being made of uniform diameter from each end, and continued parallel with the axis, until the

55.



54.



two cuts meet in the centre; very short pieces may be thus divided from the one end only. When the rings are large and thin, it is desirable to plug them at one or both ends, with a thin piece of *dry* wood, turned as a plug to fill the diameter, and prevent the ivory from becoming oval in the course of drying.

Fig. 55 explains the mode of preparing such an object as a snuff-box out of a solid block; that is, with the ordinary parting tool entered from the front, and the inside parting tool entered from within; the incisions of which meet and remove a series of rings. The dotted lines represent the paths of the respective tools, the shaded parts the ring obtained, and the black lines the tools themselves. An aperture must necessarily be made in the centre, of a diameter equal to the extreme width of the tool; but after the removal of the first, or central ring, a tool of considerably larger size may be used to extract a much wider ring; and a little tallow or oil applied to the parting tools, will, in a great measure, prevent the shavings of the ivory from sticking to them and impeding their progress.

Ivory requires a similar drying, or seasoning, to that recommended for wood; as when the pieces cut out of the tooth are too suddenly exposed to hot dry air, they crack and warp nearly after the same manner as wood, and the risk is the greater the larger the pieces; and on this account ornaments turned out of ivory or wood, especially those composed of many parts, should not be placed upon those chimney-pieces which, from their size, are so close to the fire as to become heated thereby in any sensible manner.

Notwithstanding the difference between the component parts of wood and ivory, and that the latter does not absorb water in any material degree, it is subject to all the changes of size and figure experienced by the woods, and in one respect it exceeds them, as ivory alters in *length* as well as *width* whereas from the former change wood is comparatively free.

The change, however, is very much less in the direction of the length than the width; this is particularly experienced in billiard-balls, which soon exhibit a difference in the two diameters, if the air of the apartment in which they are used differ materially from that in which the ivory had been previously kept. The balls are usually roughly turned to the sphere for some months before they are used, to allow the material to become thoroughly dry before being turned truly spherical; and in some of the clubs they even take the precaution of keeping the rough balls in their own billiard-room for a period, to expose them to the identical atmosphere in which they will be used.

It may be asked, what means there are of bleaching ivory which has become discolored; the author regrets to add that he is unacquainted with any of value. It is recommended in various popular works to scrub the ivory with Trent sand and water, and similar gritty materials; but these would only produce a sensible effect, by the removal of the external surface of the material, which would be fatal to objects delicately carved by hand, or with revolving cutting instruments applied to the lathe.

Perhaps it may be truly advanced, that ivory suffers the least change of color when it is exposed to the *light*, and closely covered with a glass shade. It assumes its most nearly white condition when the oil, with which it is naturally combined, is recently evaporated; and it is the custom in some thin works, such as the keys of pianofortes, to hasten this period, by placing them for a few hours in an oven heated in a very moderate degree, although the more immediate object is to cause the pieces to shrink before they are glued upon the wooden bodies of the keys. Some persons boil the transparent ivory in pearlash and water to whiten it; this appears to act by the superficial extraction of the oily matter as in bone, although it is very much better not to resort to the practice, which is principally employed to render that ivory which is partly opaque and partly transparent, of more nearly uniform appearance.

It is imagined by some that ivory may be softened so as to admit of being moulded like horn or tortoiseshell: its different analysis contradicts this expectation; thick pieces suffer no change in boiling water, thin pieces become a little more flexible, and thin shavings give off their jelly, which substance is occasionally prepared from them. Truly, the caustic alkali will act upon ivory as well as upon most

animal substances, yet it only does so by decomposing it; ivory, when exposed to the alkalies, first becomes unctuous or saponaceous on its outer surface, then soft, if in thin plates, and it may be ultimately dissolved, provided the alkali be concentrated; but it does not in any such case resume its first condition.

Ivory is not in all cases used in solid pieces, to which the foregoing remarks principally apply; but is frequently cut into thin leaves and glued upon fabrics of wood, for the manufacture of small ornamental boxes, and works of various kinds, after the manner of the veneers of wood, or the plates of tortoiseshell; it is also used in buhl works, combined with ebony. Such thin plates are usually cut out of the solid block, parallel with the axis of the tooth, as at *c d*, in Fig. 50, with a fine feather-edge veneer saw; but the mode introduced in Russia for cutting veneers spirally from a cylindrical block of wood, with a knife of equal length, (as if the veneer were uncoiled like a piece of silk or cloth from a roller,) has been latterly applied to the preparation of ivory into similar veneers, converting the cylinder of ivory into one ribbon, probably by the action of a reciprocating-saw.*

The modes pursued in these veneered works are analogous to those to be described in the article in reference to woods; it is, therefore, only necessary to add a few words on the white-fish glue, or "Diamond cement," as it is sometimes called, which is very often used for ivory-work, both in attaching ivory to ivory, and ivory to wood.

This cement is made of isinglass, (which is prepared from the sound, or swimming-bladder of the sturgeon,) dissolved in diluted spirits of wine, or more usually in common gin. The two are mixed in a bottle loosely corked, and gently simmered in a vessel containing boiling water: in about an hour the isinglass will be dissolved and ready for use; when cold, it should appear as an opaque, milk-white, hard jelly; it is remelted by immersion in warm water, but the cork should be at the time loosened, and it may be necessary, after a time, to add a little spirit to replace that lost by evaporation. Isinglass, dissolved in water alone, soon decomposes.

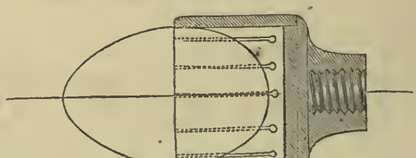
Factitious ivory and tortoiseshell have been prepared in France in thin plates or veneers.

Having adverted to many animal substances suitable to the mechanical arts, obtained from various inhabitants of the land and water, let me, in conclusion, mention some that are obtained from the feathered tribes—namely, the eggs of birds; which, although of limited application in the arts of embellishment, have at all ages served as models or standards of beautiful form.

They may be made to answer in a very perfect manner for the bodies of vases, the feet and upper parts of which are turned out of wood or ivory; for this purpose the egg-shells have been commonly used in their entire state, a hole having been made at the top and bottom for the extraction of their contents, and the attachment of the remaining parts. I have now the pleasure to bring before the reader a method of cutting the shells of the eggs of our various domestic fowls, and other birds, for the formation of vases with *detached* covers.

In the accompanying drawing is represented the nose of a lathe, with an egg chucked ready for cutting. Fig. 56 is the section of a chuck for holding the eggs to prepare them for the chuck represented in Fig. 57.

56.



57.

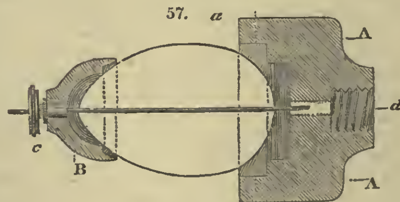


Fig. 56 is what is generally termed a spring chuck, and is made by rolling stout paper, thoroughly moistened with glue, upon a metal or hard-wood cylinder, the surface of which has been greased to prevent the paper adhering to it, and upon which it must remain until perfectly dry, when it may be removed, and cut or turned in the lathe as occasion may require.

This sort of chuck is very light, easily made, and well adapted for the brittle material it is intended to hold. Before fixing the egg in it, the inner surface should be rubbed with some adhesive substance, (common diachylon answers exceedingly well;) when this is done, the egg should be carefully placed in the chuck, the lathe being slowly kept in motion by one hand, whilst with the other the operator must adjust its position, until he observes that it runs perfectly true; then, with a sharp-pointed tool he must mark the centre, and drill a hole sufficiently large for the wire in the chuck, Fig. 57, to pass freely through.

When this is done, the egg must be reversed, and the same operation repeated on the opposite end; its contents must then be removed by blowing carefully through it: it is now ready for cutting, for which purpose it must be fixed in the chuck shown in Fig. 57, which is made as follows:

A is a chuck of box, or other hard wood, having a recess turned in it at *a b*, into which is fitted a piece of cork, as a soft substance for the egg to rest against. B is a small cup of wood, with a piece of cork fitted into it, serving the same purpose as that in A. A piece of brass, *d*, is to be firmly screwed into the chuck A, and into that a steel wire, screwed on the outer end.

* Monsieur H. Pape, of Paris, pianoforte manufacturer, has taken out patents for this method of cutting ivory spirally into sheets. A specimen, 17 inches by 38 inches, and about one-thirtieth of an inch thick, glued upon a board, may be seen at the Polytechnic Exhibition in Regent-street, and M. Pape advertises to supply sheets as large as 30 by 150 inches. He has veneered a pianoforte entirely with ivory.

ANIMAL STRENGTH. Of all the first movers of machinery, the force derived from the strength of man or other animals, was first used; and at present, in a multitude of cases is still the most convenient. As horses were formerly employed for the same purposes as water-wheels, wind-mills, and steam-engines now are, it has become usual to calculate the effect of these machines as equivalent to so many horses; and animal strength becomes thus a sort of measure of mechanical force.

When an animal is at rest, and exerts its strength against any obstacle, then the force of the animal is greatest, or the animal when standing still, will support the greatest load. If the animal begins to move, then it cannot support so great a load, because a part of its strength must be employed to effect the motion, and the greater the speed with which the animal moves, the less will be the force exerted on the obstacle, or the less will be the load which it is able to carry, for the greater will be the portion of its strength directed to the movement of its own body; and there will be a speed with which the animal can move and carry no load, but where the whole of its strength is employed in keeping up its velocity.

It is clear that in the first and last of these cases, the useful effect of the animal is nothing, in a mechanical point of view. There must however be a certain relation between the load and speed of the animal, in which the useful effect is a maximum. It has been found that the mechanical effect of any animal at work during a given time, is greatest when the animal moves with one-third of the greatest velocity with which it can move unloaded, and the load which it bears is four-ninths of that which it can only move. The mechanical effect of any animal depends upon the load which it carries, and the speed with which it moves, conjointly; and thus to find the mechanical effect of an animal, we have only to multiply the load by the speed; hence the mechanical effect of a man carrying a load of 60 lbs., and moving at the rate of 3 feet in the second, is $3 \times 60 = 180$. When a man goes up a stair unloaded, his quantity of action is the greatest possible, but his useful effect is nothing. When he is loaded his quantity of action is less, but his useful effect is more than formerly. In fact, it was found by Coulomb, that the greatest useful effect was produced when the weight which the man bore was 0·756, or $\frac{3}{4}$ of his weight; or assuming the weight of the man to be 150 lbs., the load would be $112\frac{1}{2}$ lbs.

When a man travels unloaded on a level road for several days, he can hardly walk more than 31 miles a day, which gives for the quantity of a man's action in this way 7700 lbs., carried 1094 yards. The quantity of action of a man walking up a stair, is to that when he walks on a level road, as 1 to 17.

The following table exhibits the average amount of mechanical effect produced by men and animals in different applications; the animal working with a mean velocity and effort during an average day's work, thereby producing the maximum effect.

Nature of the work.	Effort exerted.	Velocity per second.	Effect per second.	Duration.	Mechanical effect per day.
	Pounds.	Feet.		Hours.	
Man working at a lever, as in pumping, ...	10.5	3.5	37.45	8	1.078.560
" at a crank. Length of crank 16 to 18 inches; height of axis of shaft, 36 to 39 inches, . .	17.	2.4	40.8	8	1.175.040
" tread-mill at level of axis, ...	128.	0.48	61.44	8	1.769.472
" " " at angle of 24° from the vertical, .	25.$\frac{2}{3}$	2.25	57.75	8	1.663.200
" at a vertical capstan, ...	25.$\frac{1}{2}$	1.9	48.45	8	1.395.360
Horse at a whim gin not less than 20 feet radius, .	153.	2.9	443.7	8	12.778.560
Draught by traces, according to Gerstner: Weight.					
Man, ... 150	30.	2.5	75.	8	2.160.000
Horse, ... 600	120.	4.	480.	8	13.824.000
Mule, ... 500	100.	3.5	350.	8	10.080.000
Ox, ... 600	120.	2.5	300.	8	8.640.000

Desaguliers and Sweaton state the strength of a horse to be equivalent to five men; French writers to seven; Dr. Gregory to six. It is however to be remarked in comparing the strength of a horse with that of a man, that the most advantageous way to apply the strength of the one, is the least advantageous to the other. The worst way to apply the strength of the horse, is to make him carry a weight up a steep hill, while the structure of man fits him very well for that purpose.

When a horse is employed in a gin, as is often practised in grinding and threshing mills, it is desirable to give as great a diameter as possible to the circle in which the animal walks. In practice it may be stated, that the diameter of the gin walk ought not to be less than 25 or 30 feet.

According to Desaguliers, a horse's power is equivalent to 44000 lbs. raised one foot high in one minute of time. During 8 hours, according to Watt, 33000 lbs.

ANNEALING. Glass, cast iron, and steel, together with other substances, when heated, and then allowed suddenly to cool, become hard and brittle, a circumstance which often renders them unfit for the purposes for which they are intended. To obviate this inconvenience, these bodies are, when heated, allowed gradually to cool, and this process is called annealing. Glass vessels after having been blown, are placed in an oven called the *leer*, which is situated immediately over the great furnace, where they are allowed to remain gradually cooling for a greater or less time according to their thickness. The best way of annealing steel, is to render it red hot in a charcoal fire, taking care that the metal be completely covered, and then allowing the fire to go gradually out of its own accord. Cast iron cannot be managed in this way, as, being bulky, the expense of charcoal would be enormous; it is therefore usual to employ turf or cinders, the process being otherwise conducted the same way as with steel. In annealing cast iron, it is not desirable that the metal should be brought to any more than a red heat, as otherwise the smaller pieces, and thin bars might not only bend, but even melt. In annealing cast iron when the pieces are numerous, and the fire too small, or, when it is suspected that the heat of the fire when left to itself may become too great, the pieces are, when red hot, buried in dry saw dust, and in that state allowed to anneal. One great advantage of annealing cast iron, is, that if it is afterwards subjected to a partial heating, it is less liable to warp than it would otherwise be. The character of cast

iron is not in any way altered by annealing, except that it is rendered more malleable. Cast iron when employed in cutlery, is commonly bedded in some poor iron ore, or some substances which give out oxygen, and kept in a state little short of fusion for twenty-four hours; it is then found to be in a state not unfit for some kinds of edge tools and nails, and to retain a considerable portion of that malleability imparted to it by annealing. It is remarkable, that annealing makes copper hard and brittle, and that sudden cooling has the contrary effect. See IRON.

ANNIHILATOR. See FIRE ANNIHILATOR.

ANTHRACITE COAL. See COAL.

ANTIMONY, a metal usually found in a crude state combined with sulphur, of a bluish-white color crystalline texture, brittle and easily pulverized.

Manufacture.—The smelting of this metal is very simple. The crude ore is picked by hand; the pieces are broken to the size of an egg; and by means of a hand hammer, the gangue, such as quartz, barytes, or carbonate of lime is removed. These pieces may be heated in an earthenware pot, in the bottom of which is a small aperture. The sulphuret of this metal, melting at a very low heat, will flow out from the gangue, and may be gathered in another pot set below. The operation used to be performed in this manner; but as it is expensive, the ore is at present melted in a reverberatory furnace, the hearth of which is very concave, and formed of sand. In the centre of the hearth, at its deepest part, there is a tap-hole which communicates with one of the long sides of the furnace. The ore on being sorted, is spread over the hearth of the furnace, and is there melted. The tap-hole is stopped by dense coal-dust, while the reduction is going on.

Uses of Antimony.—Besides its employment in medicine, it is much used for forming alloys; of these type-metal, and anti-friction-metal—which is type-metal with the addition of copper—are those most used. Eighty parts of lead and twenty of antimony form type metal; to this commonly five or six parts of bismuth are added. Tin 80 parts, antimony 20, is music metal; it is also composed of 62.8 tin, 8 antimony, 26 copper, and 3.2 iron. Plate pewter also contains from 5 to 7 per cent. of antimony; 89 tin, 7 antimony, 2 copper, 2 iron, is one of these compositions. Britannia metal contains frequently an equal amount of antimony. Queen's metal is 75 tin, 8 antimony, 8 bismuth, and 9 lead. Antimony and tin, melted together in equal parts, form a moderately hard, brittle, but very brilliant alloy, which is not soon tarnished, and is frequently employed for small speculums in telescopes. Crude antimony is employed for purifying gold.

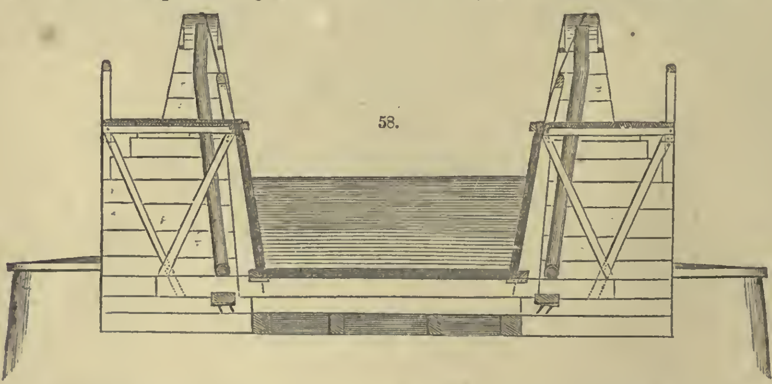
ANVIL. See FORGING.

APPLE-TREE. See WOODS, *varieties of.*

APRICOT-TREE. See WOODS, *varieties of.*

APS. See WOODS, *varieties of.*

AQUEDUCT, a conduit for water: as an illustration of an Aqueduct for the conveyance of a canal across a river we instance the Aqueduct Wire Suspension, over the Alleghany River at Pittsburg, constructed under the superintendence of John A. Roebling, at the western termination of the Pennsylvania Canal. This work consists of 7 spans, of 160 feet each, from centre to centre of pier. The trunk is of wood, and 1140 feet long, 14 feet wide at bottom, 16½ feet on top, the sides 8½ feet deep. These, as well as the bottom, are composed of a *double* course of 2½ inch white-pine plank laid diagonally, the two courses crossing each other at right angles. The bottom of the trunk rests upon transverse beams, arranged in pairs, four feet apart; between these, the posts which support the sides of the trunk are let in with dovetailed tenons, secured by bolts. The outside posts which support the sidewalk and tow-path, incline outwards, and are connected with the beams in a similar manner. Each trunk post is held by two braces, 2½ × 10 inches, and connected with the outside posts by a double joint of 2½ × 10. The trunk-posts are 7 inches square on top, and 7 × 14 at the heel; the transverse beams are 27 feet long



and 16 × 6 inches; the space between two adjoining is 4 inches. It will be observed that all parts of the framing are double with the exception of the posts, so as to admit the suspension rods. Each pair of beams is supported on each side of the trunk by a double suspension rod of 1⅛th inch round iron, bent in the shape of a stirrup, and mounted on a small cast iron saddle, which rests on the cable. These saddles are connected on top of the cables, by links, which diminish in size from the pier towards the centre. The sides of the trunk set solid against the bodies of masonry, which are erected on each pier and abutment as bases for the pyramids which support the cables. These pyramids which are con-

structed of 3 blocks of a durable, coarse, hard grained sand-stone, rise 5 feet above the level of the sidewalk and towpath, and measure 3×5 feet on top, and $4 \times 6\frac{1}{2}$ feet at base. The ample width of the tow and foot path is therefore contracted on every pier; but this arrangement proves no inconvenience, and was necessary for the suspension of the cables next to the trunk.

The caps which cover the saddles and cables on the pyramids rise 3 feet above the inside or trunk railing, and would obstruct the free passage of the tow-line; but this is obviated by an iron rod which passes over the top of the cap and forms a gradual slope down to the railing on each side of the pyramid.

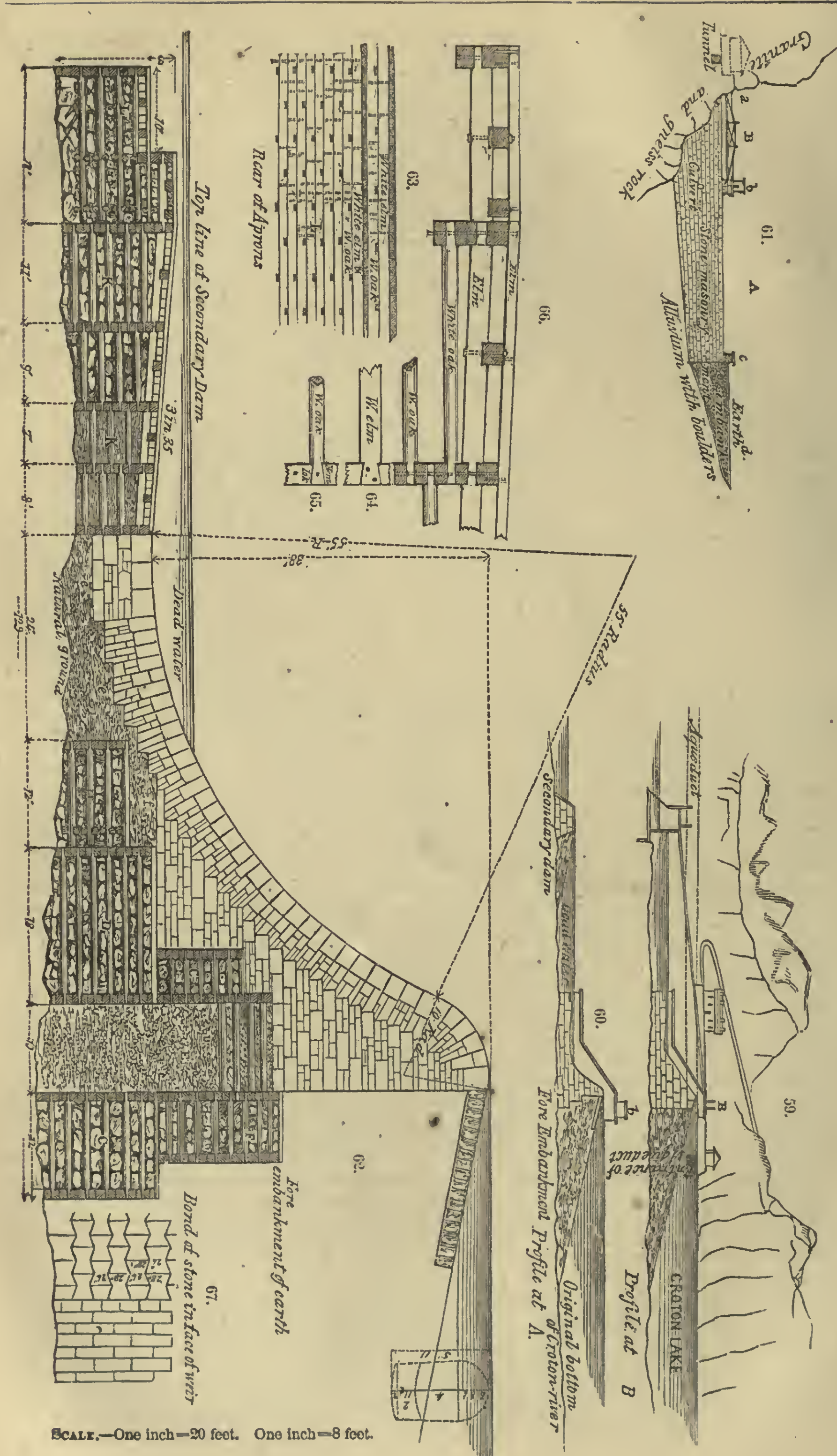
The wire cables, which are the main support of the structure, are suspended next to the trunk, one on each side; each of these two cables is exactly 7 inches in diameter, perfectly solid and compact, and constructed in one piece from shore to shore, 1175 feet long; it is composed of 1,900 wires of $\frac{1}{8}$th inch thickness, which are laid parallel to each other. Great care has been taken to insure an equal tension of the wires. Oxidation is guarded against by a varnish applied to each wire separately; their preservation, however, is insured for certain by a close, compact, and continuous wrapping, made of annealed wire, and laid on by machinery in the most perfect manner. The extremities of the cables do not extend *below* ground, but connect with anchor chains, which in a curved line, pass through large masses of masonry, the last links occupying a vertical position: the chains below ground are imbedded and completely surrounded by cement. Where the cables rest on the saddles, their size is increased at two points by introducing short wires, and thus forming swells, which fit into corresponding recesses of the casting. Between these swells the cable is forcibly pressed down by three sets of strong iron wedges, driven through openings which are cast in the side of the saddle.

AQUEDUCTS, for the water supply of cities. The Aqueduct of Spoleto, constructed in 741 by Theodoric, king of the Goths, to communicate with the town of Spoleto, is situated on the summit of a mountain. It is one of the handsomest structures of the kind, and remains entire to the present day. In crossing the river *De La Morgia*, the channel-way is supported upon two tiers of Gothic arches, the lower containing ten grand arches, and the latter thirty. The length of this arcade is 800 feet, the breadth 44, and the height 420. The Aqueduct of Caserta, built in 1753 by Charles III. of Naples, is also an expensive and gigantic structure; one of its arcades consisting of three tiers of arches, 1724 feet long, and 190 feet in height. In France, that which conducts the waters of St. Clements, and Du Boulidou to Montpelier, is perhaps the most beautiful. It was built under the superintendence of M. Pitot, and required thirteen years for its completion. The principal arcade is 90 feet high, and consists of two tiers—the lowest containing 90, and the upper 210 arches. That of Arcueil deserves next to be noticed. It was originally built by the Emperor Julian, A.D. 360, to bring water to Paris, and supplied the palace and hot-baths, but was destroyed by the Normans. After it had been in disuse for 800 years, it was rebuilt in 1634; again repaired in 1777; and fresh sums have lately been devoted to the same purpose by the city of Paris. The arcade over the valley of Arcueil consists of 25 arches, is 72 feet high, and 1,200 feet long. The Aqueduct of Lisbon, completed in 1738, is about three leagues in length, and in some part of its course has been excavated through hills; but near the city it is carried over a deep valley, for a length of 2,400 feet, by several bold arches, the largest of which has a height of 250 feet, and a span of 115 feet.

AQUEDUCT, CROTON, for the supply of the City of New York. The Croton River rises in Putnam County in three springs, whose rivulets unite near Owentown; its water is increased by the surplus of several lakes, which collect the water of the country by different small streams above and under ground. The route for the conduit canal commences near the village of Mechanicsville, runs along the left shore (looking downward) of the Croton, and the left shore of the Hudson River, and crosses Harlem River by High Bridge to the city. The execution of the work was intrusted to Mr. John B. Jervis, a practical and experienced engineer, who had been previously engaged in the execution of state canals.

The line of the aqueduct was portioned off into 4 divisions of 10 to 11 miles extent each, by Mr. Jervis the chief engineer. 1st division contained the dam, and stretched some distance below Sing-Sing, the 2d to Cook's run, the 3d to Fordham Church, and the 4th to the distributing reservoir. The whole amount of the work was given out in 99 Sections, one after the other, under contract.

THE CROTON DAM.—At the above-mentioned point, the dam was erected in order to raise the water, and to form the Croton lake. Fig. 61 shows the profile of the river. At first a length of only 90 feet was given for the dam B, and this part was erected after the profile of Fig. 59, with a construction similar to that of Fig. 62, extending then only from *a* to *b*, Fig. 61, occasion for which was given by the rock lying here affording a good foundation: the remainder of the river profile to *d*, was to be filled with an earth embankment. A considerable freshet, however, carried away this embankment when partly completed, and it was resolved to extend the stone dam 180 feet further, to *c*. For the erection of this part, A, Figs. 61 and 62, the bottom of the river was cleared from mud and boulders, and the piers C and D, of 12 inch hemlock timber, successively built up; the walls were connected together by ties, and filled with stone closely packed in; the top was covered with six-inch plank of white pine, and treenailed: upon this planking, the timber-piers F and G were erected, but only F covered with plank. While erecting those piers, the space E was filled with concrete, and the piers near the top connected with ties. Both these piers, together with their filling of concrete, being the armature of the dam, served at the same time for a coffer-dam against the water above. Against G, another timber pier was in like manner constructed, with but one timber wall; in place of the other, anchors of round timber were laid in, and with the ties joggled together. The timber of these piers is of hemlock, 12 inches by 12, the ties of white oak, 7 inches thick at the smaller end, framed with single dovetails 4 inches thick, Fig. 65, and fastened with one-inch treenails, which are placed 10 feet from centre to centre. The pier-timbers, Figs. 63 and 66, are treenailed 30 inches deep, with 2-inch treenails of white oak. These nails are sometimes put nearer together, and the ties likewise. The planking is of white pine. When the timber piers had reached a certain height, the piers K K, of four compartments, were put down, two of which, the nearest to low water, were packed out with stone; the two others were filled with concrete, and formed the coffer-dam against the water below the dam. The courses were of 12 by 12 inch hemlock; the ties of oak, 8



SCALE.—One inch=20 feet. One inch=8 feet.

inches at the smaller end, and 6 feet apart from centre to centre; the treenails of the squared timber the same. The uppermost of them are made of elm and white oak, treenailed every 3 feet, 30 inches deep, 2½ inches in diameter. The upper ties, Figs. 64 and 66, are of elm 12 inches square; to this course of ties a bed timber of white elm is joggled and secured by iron screw-bolts, Fig. 66. Across these bed timbers or caps, an apron-planking of 6-inch elm is fastened by 1½-inch locust (robinia pseudo acacia) treenails of 13 inches in length. Against the rear of this timber pier the one marked L was erected; against the back-water only, it has a regular timber wall, Fig. 63: the ties are secured by anchors. A part of the apron planking of this pier is laid horizontally in connection with the apron of the pier K; the remainder is put three feet lower, Fig. 62. After the pit had been laid dry by pumps, the ground and the space at *f* were filled in with concrete and levelled off. On this bed the body of the dam was by degrees erected of hydraulic stone-masonry, according to the bond, Fig. 67, and the courses of face-stone for the weir laid down. This face-work is of granite, cut with such closeness as to allow the stone to be laid with a joint not exceeding three-sixteenths of an inch. The masonry is laid in horizontal courses to 3 feet from the extrados of the face-work, where it is in courses corresponding with the radii. In front of the lip of dam below the head-water, a fore-embankment, Figs. 59, 60, and 62, was formed of earth, and its upper part secured with a dry stone-pavement 2 feet thick.

In the part of the dam first erected, B, Fig. 61, at *b*, and Fig. 60 at *b*, a waste-weir is constructed, in order to draw off the water of the lake from a greater depth; it consists of a well with culverts having two sets of gates, all of which are protected with a small stone-house, Figs. 60 and 61, at *b*; which can be reached by the bridge B, Figs. 59 and 61.

At a distance of 300 feet from the lip, a secondary dam, Figs. 59 and 60, is constructed; it is erected of round timber, filled up with dry stone. The object of this secondary dam is to divide the head of water, and by means of the water-basin formed by it, to break the body of water running over the weir, and to keep the wood-work of the timber-piers K and L, under water. Near the left shore a waste-weir is constructed in this dam, in order to let off the water from the basin when required.

By the construction of the Croton dam the water was raised 40 feet, whereby the river passed its shores and formed the Croton lake: this is the collecting-reservoir of the aqueduct, containing in it, at a depth of 6 feet, 500000000 gallons of disposable water, above the level that would allow the aqueduct to discharge 35000000 gallons per day;—sufficient for 1750000 inhabitants, at the rate of 20 gallons daily per head, including manufactories, shipping, watering streets, gardening, baths, &c. The flow of the Croton is about 27000000 gallons in 24 hours, at the lowest stages, which continues, with moderate rains, from two to three months in the year. Whenever the wants of the city may require the above-mentioned amount, it will be necessary to draw from those 500000000, daily, 8000000 to make up these 35000000. The amount of the reservoir would thus afford a supply for 62½ days. Never has the water in summer been so low. The supply of the Croton from its daily flow, aided by the reservoir, may therefore be taken, with great confidence, at 35000000 gallons; and when the day arrives that will require a larger quantity, it may be obtained by constructing other reservoirs further up the stream, where there are abundant facilities for such purposes.

Profile of the Aqueduct.—At the first consideration of the adopted plan, to conduct water from the Croton river, an open trapezoidal canal was proposed. The flow of the water over earth and rock might, however, impregnate the conduit-water therewith;—and as a good deal might sink into the bottom, it became necessary to make the bed waterproof; to do this with tight earth seemed insufficient, though brick with concrete under it might answer. The open canal remained, however, exposed to the sun and to evaporation, as well as to the wading of cattle, to bathing, and to being filled up with earth, boulders, and snow washed in; and might, in fine, freeze out in winter; it became necessary, therefore, to cover it, as had been found indispensable already, at deep-cuts, and in the vicinity of villages. A protection with a kind of wooden roof was some time under discussion, (seeming economical,) having the deep-cuts and tunnels arched. This mode of roofing, however, did not seem impenetrable to frost and heat; it was resolved, at last, to arch the whole, notwithstanding the great expense.

The artificial Croton lake stretches more than 5 miles on the line of the original bed of the river, which makes the total length of the whole work amount to 50 miles.

The regulation of all the measurements in heights and depths was taken from a grade-line or planum which is 7 inches below the intrados of the inverted arch at the bed of the aqueduct, being the base-line or basis-surface of the aqueduct-masonry, in cuttings into the natural ground.

Length, Inclination, and Grade.—The fall of the aqueduct on the continent is 0.021 per hundred, or 1.1088 feet per mile. The roofing-arch follows accurately this inclination, except a distance of 2276 feet next the dam, which runs horizontally at the height of the lip of the dam. At the entrance, 2.93 feet were added to the height, which brought this to 11 feet 5 inches in the clear, (Fig. 62.) From the lower intrados the inclination is 0.0113 per 100, or 0.59664 feet per mile, at a distance of 4.949 miles, where it meets the general inclination and the profile of the aqueduct, as shown in Figs. 68, 69, 70 This arrangement, which, in a certain way, can be considered as an extension of the lake, renders it possible to draw water from a depth of 11 feet 5 inches, and to carry it, under influence of its head, with less fall, over this distance. At the level of the lip of the Croton dam the aqueduct has still a capacity to draw off 35000000 gallons every 24 hours, as experiment has shown.

Table of Lengths and Inclinations.

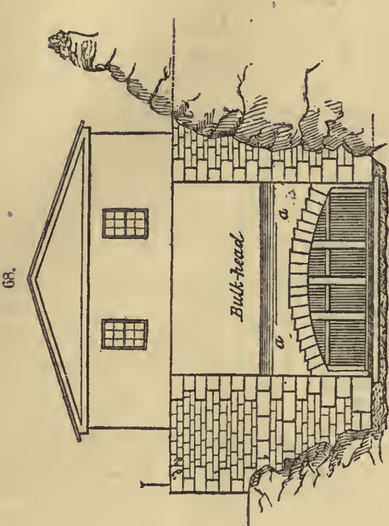
	Distances in Miles.	Distances in Feet.	Fall in feet.
From the dam to the meeting of the general inclination...	4.9490	26130	2.9507
From here to Harlem river the general inclination 0.021 per 100 or 1.1088 feet per mile of 5280 feet...............	27.9316	147479	30.9700
At the aqueduct-bridge of Harlem river to the general inclination 2 feet are added, the water being carried over in pipes by a siphon of 12 feet	0.2750	1450	2.3450
To Manhattan valley the general inclination of 1.1088 feet per mile..	2.0140	10635	2.2334
Across Manhattan valley the water passes in a siphon of 109 feet head, for that reason 3 feet are added to the general inclination	0.7917	4180	3.7783
From here to the receiving-reservoir 9 inches per mile	2.1727	11471	1.6295
From the influence-gate of this reservoir to its effluence-gate	0.1720	908	0.0000
To the distributing-reservoir the water is carried in a siphon by pipes; for the entire distance	2.1760	11489	4.0000
Distributing-reservoir...	0.0800	420	0.0000
These 47.9069 feet form the fall at the bottom of the aqueduct; at the head this bottom is............... 11.4633 F. below the surface of the lake, but only....... 8.2000 " at the discharge in the receiving-reservoir	40.5620	....	47.9069
which gives .... 3.2633 " difference, added to the fall at bottom; this makes the entire fall, or the accurate difference between the surface	....	....	3.2633
of the Croton lake and that of the distributing-reservoir	....	....	51.1702
When to this extension of the aqueduct that of the large mains is added, which is about..............................	4.0000		
we have the following as the entire length of aqueduct from its head to the distribution of the water, viz.:—	44.5620		

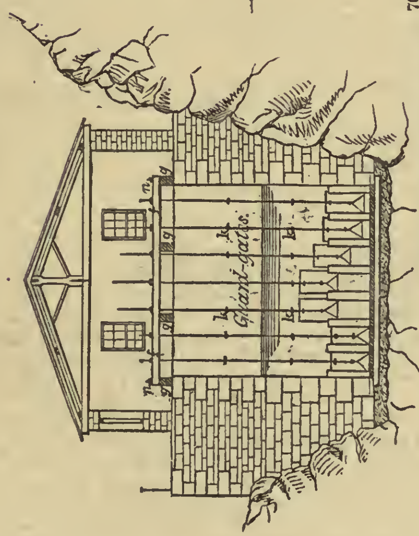
Construction of Aqueduct-canal.—Where the masonry of the aqueduct is cut in level ground or side-hills, a course of concrete 3 inches high is laid under the whole extent of masonry; under the extrados of the inverted arch, as high as the shape of the extrados required. Where water-veins were met, and in loose ground, or where the depressed ground made foundation walls necessary, the concrete bedding was put 12 inches high as broad as the clear width of the aqueduct; but under the side walls only 6 inches. In both cases each of the side walls was carried up 13 inches high perpendicularly, by which the spring-line of the inverted arch was reached; after this the inverted arch was turned ½ a brick 4 inches thick, the stone part of the side walls carried up 4 feet high, and on both sides plastered ⅜ inch thick with hydraulic mortar. When these walls had set, the inner facing, ½ a brick 4 inches thick, was carried up; at last the roofing-arch, 1 brick 8 inches thick; then the spandril-backing, over which and the upper part of the extrados, plaster of ⅜ inch thickness was laid on and smoothed off with the trowel. Where suitable stone was to be had near, the side walls could be carried up; also the roofing-arch, which in this case was turned 12 inches thick; this, however, has been carried into execution in but few instances. The courses of masonry were levelled off every 12 inches, and no stone put in which reached through the wall or raised over the course of 12 inches; granite, or gneiss of the most sound quality, was used.

The hydraulic mortar at tunnels, deep-cuts in earth and rock, had the proportions of 1 part cement to 3 sand; upon foundation-walls, however, 1 part cement to 2½ sand in volume; the same proportion for concrete. The sand for concrete, containing coarse and fine grains, was first mixed with water, then there was added to it from 2 to 2½ broken stone of the size of 1¼ inch, or the same amount of coarse gravel, and worked till the mass became uniform, and the broken stone completely covered and bedded in the mortar. Immediately after this preparation the concrete was laid and settled with a stamper till the surface had the appearance of an even floor: the courses were laid not over 6 inches thick. For brick masonry the proportion of cement to sand was 1 to 2; the mortar for vertical joints was put to the brick before laid, the brick forced into its bed in such a manner, that from horizontal and vertical joints the mortar readily is forced out like sausages; the superfluous mortar was then taken off and the joints smoothed immediately: only bricks of superior quality were admitted, No. 1 for the inverted arch and the facing, No. 2 for the roofing-arch.

Culverts.—In order to carry off rivers, creeks, and field-waters, underneath the aqueduct, culverts were constructed at a suitable depth. Their fall or inclination was 1 in 20; and where the upper end happened to be below the surface of the ground, generally the case at side-hills, a well was constructed, Figs. 76 and 79. The culvert, Figs. 79, 80, and 81, is one of the smallest dimensions, with bottom and roof of stone slabs; that of Figs. 76, 77, and 78, is a large one, bottom and roofing are of smooth, well-wrought stone, the side-walls only faced with it, while the backing of this face-work is of rough masonry

68.





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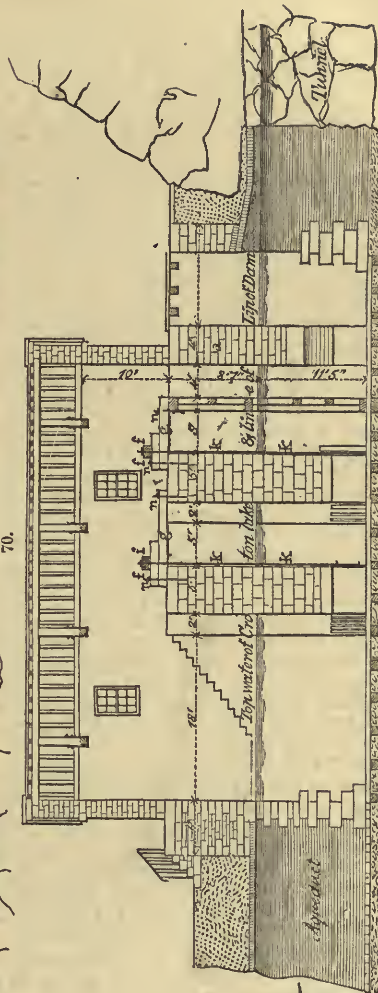

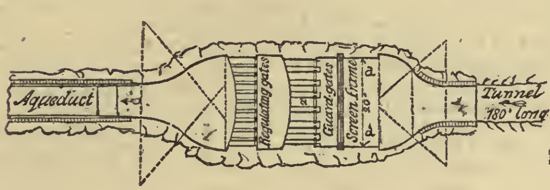

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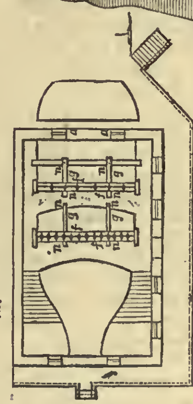


SCALE.—1 inch = 40 feet.

In the body of the foundation-wall of the aqueduct, an arch of dry stone without mortar was rolled over the extrados of culvert, Fig. 78; after this the foundation carried further up. The fall-well at the arched culverts is round in plan, Fig. 77.

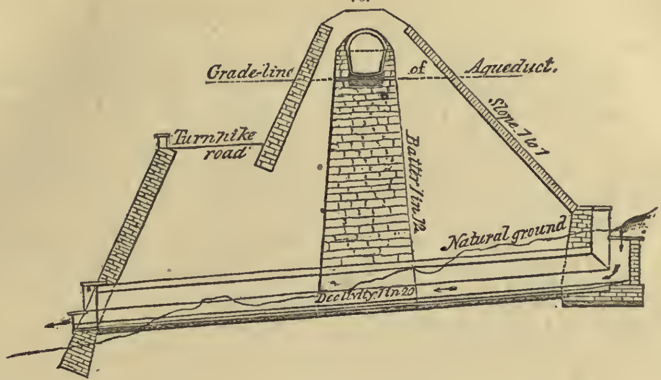
The Gateway.—From the effluence of the lake, Figs. 59 and 61, a tunnel is cut through solid rock 180 feet in length. It has no facing of masonry, and in dimensions is kept somewhat larger than the general aqueduct, only below the gateway, Fig. 70, it takes the dimensions as marked, Fig. 62, except the height, which is here greater. The ground is uncommonly favorable for the construction of the gateway, offering rock-foundations throughout. As shown, Fig. 71, the channel of the aqueduct is widened, and the water runs through an arch in the bulkhead *a a*, then passes the screen-frame, a set of guard-gates, and a set of regulating gates. The screen, formed of oak slabs, six inches by one, allowed a quantity of fish to pass through the one-inch spaces into the aqueduct. In order to prevent this, a fine brass netting was put over the screen, through which only very small fish could pass; to prevent which other artificial preparations will be required. Below the wall with the regulating gates, the width of the water-way is reduced to the general width of the aqueduct, by an ogee curve, in order to let the water into the proper aqueduct without any loss of fall.

The guard-gates with their frames are of cast-iron, made as shown in Fig. 37; *a* is the frame lined with metal. The sill is marked here let in stone, but in the case under description it is cut something into the wooden floor; *b* is the shover with the consols *c c* through which the wrought-iron rod *d d* passes—the latter has a screw cut at its upper end; *e e* is a nut, which is let into the caps *f f* and screwed. By turning right or left with a key put on the die, the rod rises or lowers, and the gate is opened or shut. On account of the considerable length of the rod, the guides *k k*, Figs. 69 and 70, are put on; they consist of cases of wrought-iron, leaded into the stone of the wall. The regulating gates with their frames are of gun metal, in order to obtain a superior tightness. The caps *f f*, Fig. 70, are secured upon the saddles *g g* by bolts. In turning to the left the female, whereby the shover is raised, the saddles with the caps press upon the base and are kept closer and closer upon their bed; in screwing right, however, they press upward. To prevent their loosening and lifting, the screw-bolts *n n n* are put in; they reach down through two courses of stone, and there they are bent; some of them are secured to the caps of the screen-frame. In shutting the gates by turning to the right, the bolts *n n* secure the caps *f f* to their places and prevent their lifting. The masonry in all parts of the gateway is of rough gneiss in hydraulic mortar, faced with well-hammered stone: the partitions between the gates are of cut stone. To keep the gates and utensils secure, a stone house is erected over the gateway.

Line of Aqueduct.—Having left the gateway, the aqueduct makes its way upon the left bank of the Croton river. After a course of one mile, it crosses Lounsberry's brook, over a culvert of 6 feet in width, 66 feet in length, the bottom of which lies 44 feet below the top of the back-filling of aqueduct. After crossing some little brooks with small culverts, the line leaves this river, having followed it for 5 miles, turns to the left and crosses the valley of India creek 6 miles from the dam; the culvert for the passage of this stream is 8 feet wide, 142 feet long, and its bottom is 58 feet below the top. A little distance further, the aqueduct is tunnelled through two hills of solid rock. The first passage, called Benvenue farm tunnel, is 720 feet in length; the second, Acker's brook tunnel, is 116 feet long. Half a mile further is another tunnel of 276 feet in length, called Hoag's hill tunnel, cut through rock. From here to Sing-Sing, several small valleys and ravines of from 20 to 32 feet in depth are crossed by the aqueduct. Immediately after the last one, there is another tunnel worked through rock, called Sing-Sing tunnel.

Sing-Sing Kill Bridge—was commonly called, while in construction, the passage of the aqueduct across the valley of the Kill river. Although the Kill is merely an unimportant brook, by frequent freshets it has worn out a large chasm, the depth of which from the top of the aqueduct to the rock bottom is 82 feet; the width measured at the top is 536 feet. Parallel to the river runs a street of the village of Sing-Sing, over which an aqueduct bridge of 20 feet in width was constructed; a little further the line of the aqueduct cut off the dwelling-house from the rest of the farm of Mr. Sing, where a passage-way 7 feet wide was constructed. Across the stream an arch of 88 feet span was required. The abutment walls of this bridge are 20 feet thick, on solid rock-foundation. The arch is constructed over an half oval, 33 feet in height, 4 feet thick at the spring-line, and 3 feet at the keystone; the granite and gneiss for it was cut with much accuracy, not allowing the joints to be over three-sixteenths of an inch thick. The spandrils were carried up solid, sloping upward, thence with hance walls and alternating openings, till 3 inches over the highest point of extrados: these openings were arched over with half a brick. Across those openings, the hance walls were connected together by bond stone. On the top of the small brick arches, a rubble masonry of 6 inches in height was laid, and the whole levelled off; on this the concrete course of 9 inches height to the extrados of the inverted arch of aqueduct. As far as the clear width of the bridge arch and its abutments extended, the construction of the aqueduct was so altered, that the side-walls were carried up 5 feet high instead of 4, as in ordinary aqueduct, and the arch was turned over a segment of 7 feet 7 inches long, 2 feet 8½ inches high. Bottom and side walls were provided with a lining of cast-iron in form and dimensions, worked in with the masonry; whereby the aqueduct was rendered absolutely water-tight above these constructions. The same iron lining was applied also at the before-mentioned street bridge. Between the attic wall and the side wall of the aqueduct, spaces were left, covered over, above the attic wall, carried up in connection with the side walls of the aqueduct, and covered with a coping stone, the whole then filled over with earth. The spaces serve not only for protection against frost from without, but also for carrying off the water falling from the sky on the back-filling, down into the hollows. Upon the extrados of the bridge-arch, the drainage water runs over the tangental surface of the spandril-backing into the dry foundation wall. The surface over which the water drains is well plastered with hydraulic mortar. The exterior masonry of both the bridges is of well-hammered stone. Throughout the structure hydraulic mortar was used. For the distance of aqueduct between the bridges and back of them to the side-hills, the rock bottom was prepared with steps, and a foundation wall of dry stone-masonry carried up The exterior faces of some thickness into the wall were laid in hydraulic mortar, and the joints pointed with the trowel.

76.



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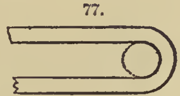

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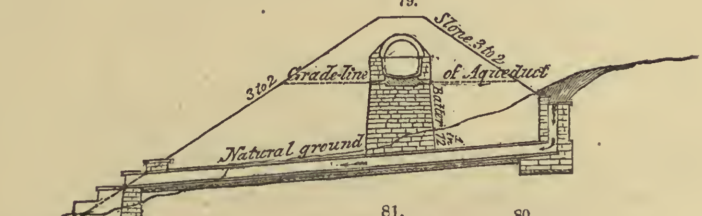

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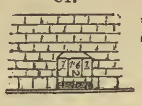

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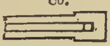

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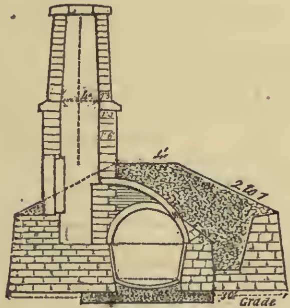

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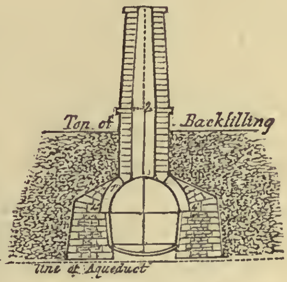

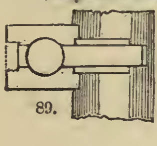

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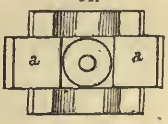
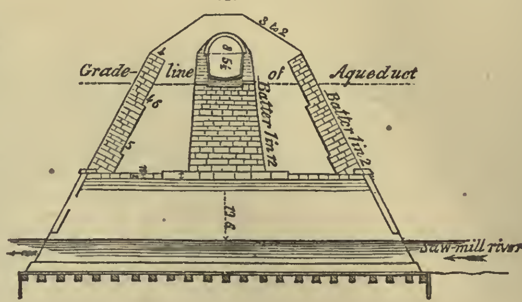


SCALE.—1 inch = 40 feet.

Continuation of the line of Aqueduct.—Below some streets running across Sing-Sing, the aqueduct proceeds further on for a mile, on quite favorable ground, and when on the land of the State prison farm, it enters into the great State prison farm tunnel, made 416 feet long, partly in rock, partly in earth. At some distance further, it is met by the small State prison farm tunnel, 375 feet, in earth: 9½ miles from the dam, after having passed Hale's brook tunnel of 260 feet in length, the aqueduct crosses the valley of Hale's brook; its culvert is 6 feet in width, 131 feet long, and 49 feet below the top of the back-filling of the aqueduct. One mile further, the line crosses Rider's brook, over a culvert 100 feet long, 6 feet wide, and 34 feet under the top of the aqueduct: 10 miles from the dam, the aqueduct crosses over the highway leading from Sing-Sing to Tarrytown by a bridge of 20 feet span. Proceeding further on, the aqueduct encounters some high land, through which a tunnel of 186 feet is driven; it is 11½ miles from the dam, designated Austin farm tunnel. From here the ground has various depressions of from 20 to 30 feet under the top of the aqueduct.

73.



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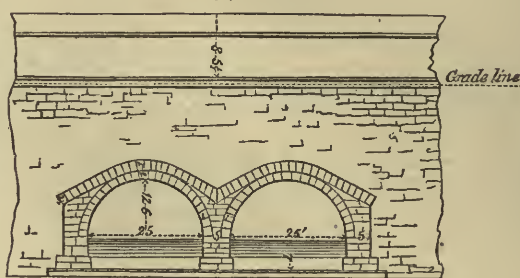


75.

At Mill river, 13 miles from the dam, the crossing-work is imposing. The depression of the valley is 87 feet below the top; the culvert or aqueduct bridge is 25 feet in width and 172 feet in length. In the extension of the next two miles, in the vicinity of Tarrytown, at five valleys in succession, small culverts of various dimensions are constructed; then the aqueduct passes a tunnel of 246 feet in length, mostly through rock, called White Plains tunnel; then Requa's brook is crossed, over a culvert of 25 feet below the top; and after this the classical ground of Washington Irving's farm and Irving's run, the latter with a small culvert.

The next structure is at Jewell's brook, and its ravine, 17½ miles from the dam; the culvert is 6 feet wide, 148 feet long, 62 feet below the top. A farm-road which could not be removed, was made to run under the aqueduct at a heavy expense; its arch is 14 feet in width, 141 feet long. Across Wilsey's brook, 18½ miles from the dam, the culvert is 49 feet below the top, 6 feet wide, and 137 feet long. Half a mile further there is a tunnel near Dobbs' Ferry, 262 feet, driven through earth, and designated Dobbs' Ferry Tunnel. Crossing Storms' brook, the depth of culvert is 40 feet, the clear width 6 feet, and the length 137.

From here the aqueduct passes several small valleys of from 10 to 15 feet in depth. At Cook's run the culvert is 4 feet wide, 132 feet long, and its bottom is 42 feet below top of aqueduct. Dyckman's brook, 22 miles from the dam, has a culvert of 8 feet in width, 120 feet in length, and is 35 feet below the top of back-filling. Then the line crosses various unimportant valleys and creeks, with small culverts, and arrives in the vicinity of the village of Yonkers, where, on account of the greater inland extension of low ground, an abrupt curve to the left was required, followed at a short distance by another to the right. The aqueduct passes through the Sawmill river tunnel, which is 684 feet, driven partly through earth, partly through rock; then it crosses the river itself, over which a bridge of two arches of 25 feet each has been erected. Fig. 73 is the cross-section of aqueduct at this point, with the longitudinal section of bridge; Fig. 74 the cross-section of bridge with the longitudinal section of aqueduct; and the last, Fig. 75, is the horizontal projection of one of the flanks; close to it is the passage for the turnpike-road, 20 feet in width, arched over a semicircle. The next work is a culvert over Nodine's run; after which a hill of considerable height is encountered, behind which the valley of Tibbit's brook comes in the way. The tunnel under this hill is 810 feet long, driven through solid rock, and called Tibbit's brook tunnel. The culvert for the brook is 6 feet wide, 107 feet long, and its bed is 40 feet below the top of the aqueduct: it is 26 miles from the dam. At some distance several small brooks are crossed: one is O'Brien's run; the largest is Acker's brook, which passes 37 feet below the top of the aqueduct. The last two miles of the line are very nearly straight, the high land offering so favorable ground, that the upper filling of the aqueduct just disappears under the surface. Here the aqueduct arrives at the strait which separates Manhattan Island from the continent.

Harlem River Bridge.—The valley of Harlem river slopes down from the before-mentioned high land, at a point which is 33 miles distant from the Croton dam, first at 20 degrees, to a piece of table-land 25 feet above tide-water, stretching over a distance of 300 feet, whence, by a second slope, it

reaches the water's edge. The tide-water has here a width of 620 feet. The bank of the island being of solid gneiss-rock, rises with a slope of 35 degrees to the height of the top of the aqueduct. The slope of this rock below water, as far as it could be examined, is steeper, and disappears under a deposite of mud mixed with sand and boulders. It is supposed this rock has connection with that of the opposite shore. In the basin formed by its depression below the strait is deposited a mass of white marble, Fig. 100, upon which the gneiss and alluvium of sand, mixed with pieces of rock and boulders, are found, upon which mud is deposited, consisting chiefly of vegetable matter.

At first it was intended to carry the conduit-water over the valley in a siphon, through iron pipes,—on the side of the continent, following the surface of the ground to the water's edge, across the water of the river upon a stone embankment, from the centre of the river, ascending to that point of the island where the aqueduct starts again. Through the body of that part of the embankment, next the island bank which is sloping up, an arch of 120 feet in width, 60 feet high, was intended, through which a passage was to be kept open for navigation with sloops and schooners of 200 tons burden. The execution of this work was already contracted for, the dredging-machine in operation, when the landholders of both the banks of the river started a lawsuit against the measure; and an act from the legislature of the State was obtained, according to which, the aqueduct was to be carried below the bottom of the sea, or above its surface at such a height, that openings of 100 feet above high-water, 80 feet in width, had to be left in order to carry on the navigation. Notwithstanding estimates and comparisons of the two methods showed a surplus in cost of 200,000 dollars for the latter, its erection was preferred.

This bridge has 15 arches, 8 of which are 80 feet in width each, by 100 feet in height above flood-tide, placed in the water, and upon both the shores 7 arches of 50 feet span each; the two abutments were founded on the gneiss rock, three upon the marble, seven on piles, the rock being without reach below the latter. With this arrangement, the conduit-water was carried across to the island in a siphon of 12 feet depression.

The manner intended of carrying the water below the bottom of the sea should here be mentioned. Following the slopes of the banks and the valley, 4 pipes of 3 feet diameter each, were to be laid 4 feet under the surface of the ground, below the bottom of the Strait; 2 tunnels, parallel to each other, 12 feet wide, 8 feet high each, 12 inches thick at bottom arch, put upon concrete, side walls and centre wall 4 feet thick each, roofing arches 16 inches thick; the extrados of both these arches covered with a course of concrete of 2 feet thickness, and the whole structure, top and sides, covered again with a stone pavement 12 inches thick, set in hydraulic mortar; the stone pavement was kept 24 feet below low-water. Each of the tunnels contained 2 pipes; the tunnels were provided with entrances, in order to examine them. It was intended to carry out the work by means of a coffer-dam on each side. The estimated cost was 636738 dollars.

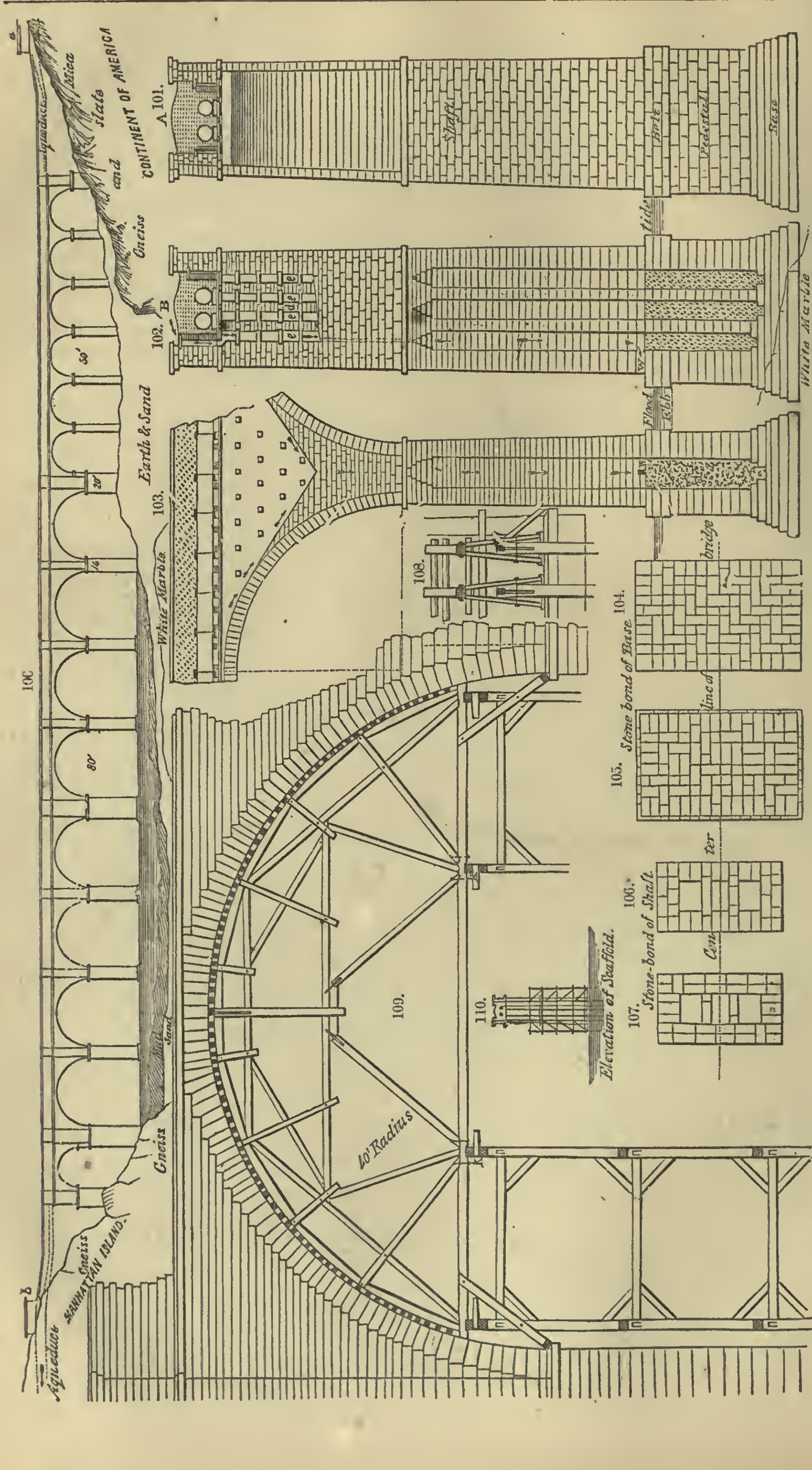
In order to reach the foundation of every pier for the high bridge, a coffer-dam was put down, the coffer or box made for each of the piers of such a height as the depth of water at its site required, together with the thickness of the mud-deposite, and 3 feet border above high-water.

In order to take the water out of the aqueduct, and let it into the pipes, and after passing over the bridge, re-discharge the same into the aqueduct, 2 gate-chambers, *a* and *b*, Fig. 100, are placed. Fig. 113 shows the ground-plan, Fig. 112 the longitudinal section, and Fig. 111 the cross-section of the influence gate-chamber, (entrance into the siphon;) *c c* is a basin, the bottom of which is level with the deepest line of the intrados of the inverted arch; *d d* are the gateways, *e e* the two pipes; the influx of the water can be regulated by the two cast-iron double gates *k k; f g h* is a waste-weir, whereby the waste water or the whole content of the aqueduct may be let off; *f* is the gateway, *g* the waste-weir well, *h* the sewer. The construction of the latter for the first 30 feet in length, is shown by Fig. 115; following the slope downward, it is funnelled into the shape and construction of Fig. 114, which leads to Harlem river. Fig. 111 is the section of gateway for the waste-weir; Fig. 112 the elevation of front with the gates *l l*. All the gates are of shape and construction as shown at Fig. 69. The rod-caps of waste-weir are connected by the bolts *m n*, Fig. 111, with the consols *n*; but the rod-caps of the gateways by the bolts *m n*, which are kept down and secured in the pier below, by the crosspiece *n*. Over the entire structure, a stone building is erected, arched with bricks, and covered with 3-inch greywacke slabs. The effluent-gate *b*, Fig. 111, at the island extremity of the bridge, is of the same arrangement in reversed order, but without waste-weir; it receives the water from the pipes of the siphon, and discharges it again into the aqueduct.

Several times the question has been asked, why this bridge, being in a certain way considered a construction of luxury, has not been carried up to the full height, reaching the water-line of aqueduct, with the construction of the latter as upon the Sing-Sing Kill bridge? The pipes could have been spared; the erection of the gate-chambers rendered needless; and what is most important, 2 feet of height had been saved, 117 feet head being left in the city, instead of 115. The reply may be:—a greater height of the structure would have required a larger and more compact model for the piers, or a more careful choice of material, and a more costly workmanship of the same; also a greater height for the attic walls upon the bridge arches; and in fine, the construction of the aqueduct itself with iron lining. All this, without doubt, would have accumulated the cost by 75000 dollars, a sum of some moment in the cost of the water-work. Considered as a monument, the bridge, as above constructed, has a sufficient height.

The beginning of the construction of this bridge had been greatly delayed. It was desirable to use the aqueduct sooner than the bridge possibly could be finished. Down the descent of the valley, then upon the embankments enclosing the coffer-dams—which by degrees had formed an unbroken embankment across the salt-water strait—then up the island-shore to the aqueduct, a 36-inch pipe was put down, through which the conduit-water provisionally was led across the valley, and the aqueduct opened on the 4th of July, 1842. The construction of the bridge went on but slowly.

Continuation of the Line of Aqueduct.—A short distance from the effluence-gate the aqueduct passes over a ravine of 30 feet in depth, immediately after which a tunnel had to be driven 234 feet through solid rock. This lies about 33½ miles from the dam, on the land of the deceased Monsieur Etienne Jumell, on that account called Jumell tunnel. Close by this tunnel is a ravine of 38 feet in


Aqueduct
Mica
Slate
and
Gneiss
CONTINENT OF AMERICA
A 101.
Shaft
Belt
Pedestal
Base
102. B
Tide
Flood
Ebb
White Marble
Earth & Sand
103.
White Marble
50'
20'
80'
Sand
Gneiss
MANHATTAN ISLAND
Aqueduct
108.
104.
Stone bond of Base
line of bridge
105.
Center
106.
Stone-bond of Shaft
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Elevation of Scaffold.
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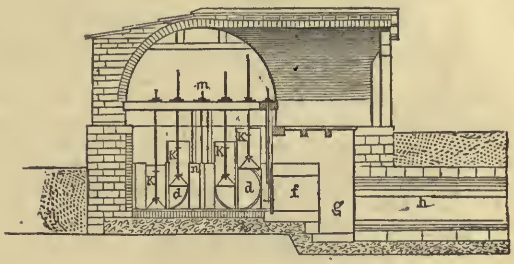

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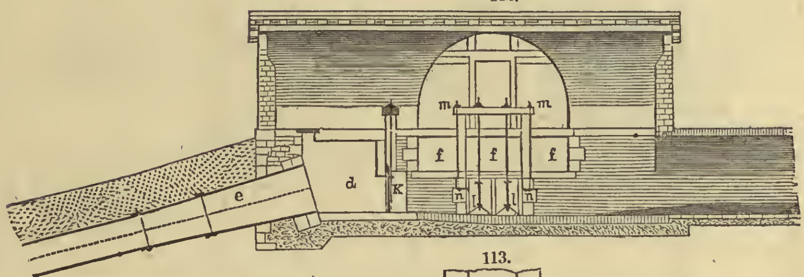

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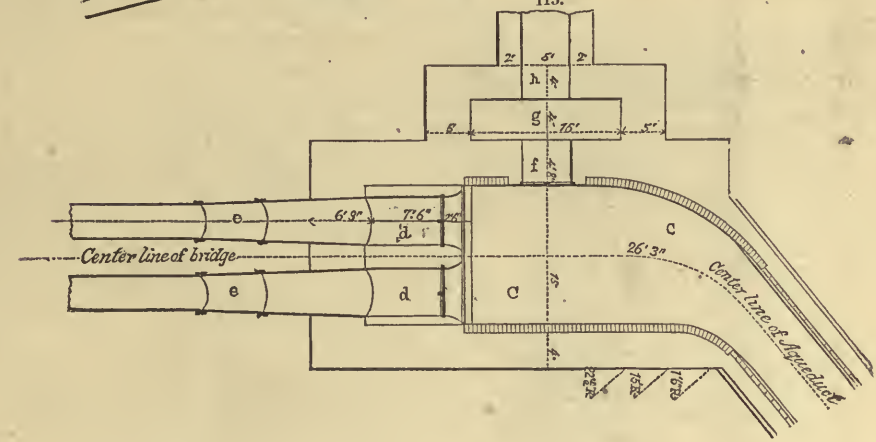

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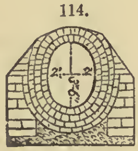

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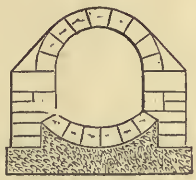

depth, and another 43 feet deep. Proceeding further 34¼ miles from the dam, the aqueduct enters into the line of 10th Avenue. Without any obstacles of consequence, it proceeds hence to the vicinity of Manhattanville, and 35 miles from the dam passes through Manhattan-hill tunnel, the longest of the whole line—worked 1215 feet through rock.

Manhattan Valley.—Having left the tunnel, the ground slopes down to a depth of 105 feet, and rises up again to grade-line; measured here, the length amounts to 4180 feet. For conducting the water across this valley, first an aqueduct of arcades was proposed, with arches of brick supported by piers of rough stone-masonry, and the aqueduct upon these in its common shape. This method of crossing would have preserved 3 feet of head-pressure for the conduit-water, but at an expense of $1200000, while the passage in pipes cost only the fifth of that sum; this was a matter of some moment, and it was concluded, therefore, to make use of 4 pipes of 36 inches each. At the end of the last-mentioned tunnel an influent-gate, similar to that of Fig. 112, was erected, only of a greater width of basin—4 pipes being required; otherwise of the same arrangement, leaving out the waste-weir. At the brow of the opposite height, called Asylum-hill, is the effluent-gate, of the same construction entirely with the influent-gate; it receives the conduit-water from the pipes, and lets it into the aqueduct again. Between

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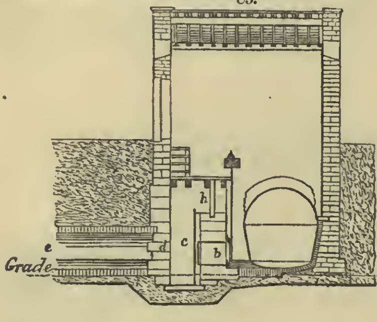

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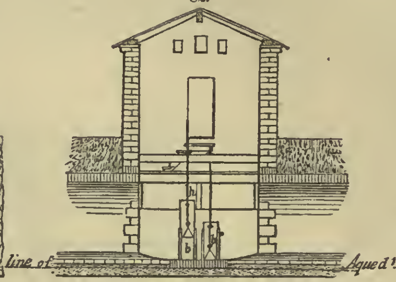

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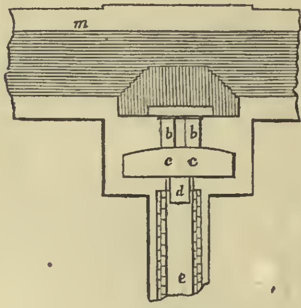

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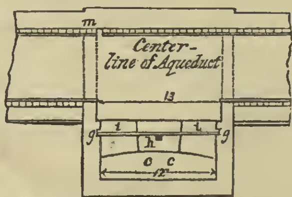

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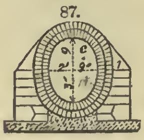

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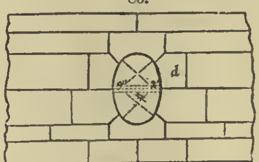


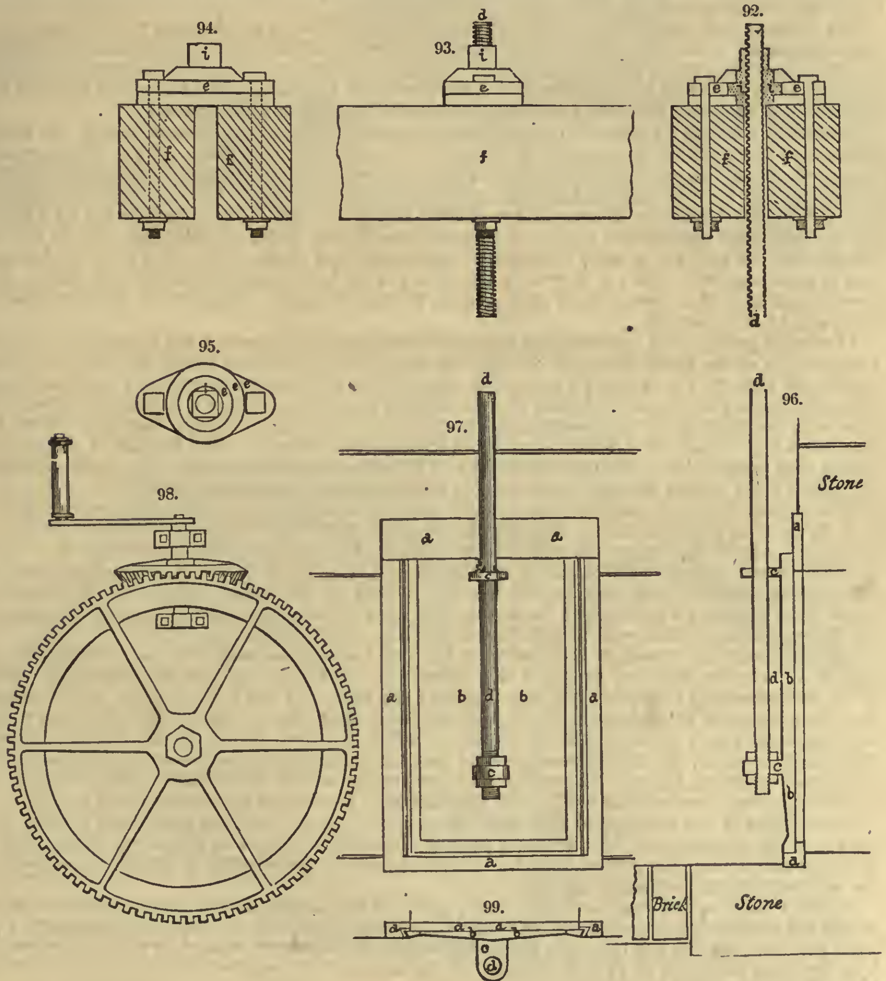
those two gates the siphon is placed, the pipes of which are partly laid in the ground; and where depressions of the ground occur, upon an embankment of earth, throughout covered with earth 4 feet high

In order to empty the pipes of the siphon when required, in cases of repair or removing deposites of sand at the deepest depression of the valley, here, just in Manhattan-street, provisions were made for a waste weir for that purpose at each pipe; waste-pipes were put in; those pipes pass through the stop-cock vault and discharge into the waste-weir well. When one of the pipes is to be emptied, both of its upper ends are closed first by the respective gates in the gate-houses, then the stop-cock in the stop-cock vault drawn open; the content of the pipe makes now its way through a pipe into a sewer, which about 2000 feet from here discharges into the Hudson river.

Continuation of the Aqueduct-line.—The declivity of the aqueduct being from here only 9 inches per mile, the water rises back as far as this from the receiving reservoir, which is merely 2.1727 miles off. To the thickness of the side-walls of the aqueduct, by degrees, 4 inches have been added, making in all, 3 feet below, and 2 feet 4 inches at the spring-line; in the same way the walls were carried higher up to 1½ feet above the spring-line of the roofing-arch. A short distance from the effluent-gate the line goes through its last tunnel, called Asylum-hill tunnel; this has a length of 640 feet, mostly broken through rock. Further on, for the greatest part of a mile, it was necessary to construct

the aqueduct thus, that its sides and back-filling reached the height of 30 feet; at the end of this, for a little distance, the ground rises again to such a height that the upper-filling of the aqueduct just disappears below it, then another valley comes in the way.

Clendenning Valley is the name given to the depression of ground which stretches across the highlands of the island. The most favorable passage for the aqueduct is offered by a line drawn 150 feet west from the axis of 9th Avenue, to which the aqueduct-line, coming from the 10th Avenue, is connected by an ogee-curve. The valley here has a length, or rather width, of 2000 feet, measured from the commencement of the upper-filling of the aqueduct, at the brow of the hill, to its disappearance on the opposite side; its greatest depth is 50 feet below the upper-filling. Looking on the map, it shows that this part of the island is laid out in streets and blocks. At this place it was designed that the streets, after being cut through and opened, should cross over the aqueduct; but, under such a considerable depression of ground as this, it was not practicable; and it was concluded to pass 6 of



these streets, viz., the 101st, 100th, 99th, 98th, 97th, and 96th, underneath. The first 5 of these streets are 60 feet wide; but 96th, being a principal street, is 100. For their passage aqueduct-bridges were applied, of 3 arches each for the first 5; a main arch 30 feet in width in the centre for the road-way; and two side arches, for the sidewalks, of 9 feet span each, over 101st and 97th streets; but of 10½ at the bridges over 100th, 99th, and 98th streets. During the construction of those bridges it was thought, by the new Water Commissioners, only some of those bridges might be required for passage for the space of 50 or even 100 years, in consequence of which the passages for 101st, 97th, and 96th streets were beforehand left out; the bridges for 100th, 99th, and 98th streets will then be spoken of here.

The dimensions of the different parts of these bridges are the same among all, with exception of the height of the pier-shafts only, which is determined by the various levels of pavement in the streets, but making only a difference of some inches. The foundation of all the piers is placed partly on rock, and partly on alluvial ground; the piers themselves, as well as the arches, being constructed of gneiss rock; the former of well-hammered stone, the latter of cut-stone. The spandrels of the arches are car-

ried up solid to the line tangental to the extrados. From here hance-walls are carried up alternating with openings, the latter being covered over with stone slabs, at a height of 3 inches over the extrados: here the whole is levelled off by a rubble-masonry of stone 6 inches thick. Upon this level a course of concrete 9 inches thick is bedded, on which the aqueduct with its iron lining is erected; on the outsides of the side-walls of aqueduct, spaces of 6 inches in width are left, in order to separate the masonry of the aqueduct from the attic-walls, and to carry the water, draining through the earth-filling, over the extrados and the spandrel-backing. The spaces of aqueduct between the various streets, and beyond them to the extremities of the valley, are supported by a dry stone-wall; stone of large size, to the thickness of 2 feet, were laid upon their broadest beds over the whole course, the interstices filled in with smaller ones, and all levelled off with smaller and smaller broken stone to the height of 2 feet, on which the following course was laid in the same manner; on a width of one foot back from the outside, this masonry was laid in hydraulic-mortar, and the joints pointed. This part of the aqueduct has a very substantial appearance.

The Aqueduct line continued.—Over a distance of seven-eighths of a mile, upon which a curve of 90 degrees is turned to the left, in three various radii, the aqueduct of masonry discharges into the receiving reservoir; upon that curve the ground has a depression of about 40 feet, and the over-filling of the aqueduct is supported by protection-walls. Here then is the termination of the aqueduct as far as it is constructed of masonry; and only some appurtenances still remain to be mentioned.

In order to keep the air which is confined in the closed aqueduct, in communication with the atmosphere, ventilators, Fig. 90, are erected at distances of every mile; buttresses *a a*, Fig. 91, are carried up on each side of the aqueduct, between which the roofing-arch is carried round 12 inches thick instead of 8 inches. In the centre of the arch thus fortified, a circular opening is left bordered with bricks or stone; upon this border the chimney-like ventilator, Fig. 90, is erected, secured at the top by a lattice. The third of those ventilators is always of larger dimensions and provided with a door to pass into the interior, Figs. 89 and 88, in order to facilitate examination and repair of the inner parts of the aqueduct in cases required. The one shown by Fig. 90 is put up before crossing Clendenning valley. The greater number of them are made of white marble, the rest of gneiss. There are of the latter kind 11 in all, and 22 of the former.

At suitable points of the aqueduct line waste-weirs are put in to draw out the water when required. There are six on the whole line, with exception of that in the gate-house before Harlem river bridge. A gateway, Figs. 82, 83, 84, and 85, is formed according to the marked dimensions; the waste-water passes through a pair of gates, *b b*, falls into the well *c c*, and discharges over *d* into the sewer *e e*. The gates with the gateway are constructed entirely as shown in Fig. 97, and already described. When the water rises higher than 5 feet 9 inches, measured from the deepest point of the intrados of the inverted arch, it runs over the lip of the breast-wall *f f*, and falls likewise into the well *c*. By means of timber or planks *i i*, put against the post *h*, and slipping in the rabbits *g g*, provision is made to keep the water in the aqueduct higher at pleasure, consequently over the mentioned 5 feet 9 inches. In the platform at *k*, an opening, provided with a trap-door, is left, through which the planks *i i* can be put in and taken out. Above all, a stone house has been erected. From without, the platform can be reached by the door and over a small stair. At *m*, Figs. 84 and 85, a rabbit is cut in the side-walls of the aqueduct, into which timber may be slid in order to shut off the same. Those waste-weirs at their places serve likewise for ventilators; the one just described is put at 142d street: those on the continent are of the same description, with unimportant differences adapted to locality.

The Receiving-Reservoir, is built between 7th and 6th avenues, and 86th and 79th streets; its area is 37.05 acres, including the top of the embankment, or 31 acres of surface of water. By means of an embankment it is divided into two divisions; the north one has a depth of 24 feet, measured down from the top of the embankment, and is filled with 20 feet of water; the southern division is 29 feet deep below the top of the embankment, 25 feet of which is water. Those depths, however, are not throughout the same; the rock-bottom near the southern embankment lies lower than this—near the northern embankment, higher. The contents of water amount to 150000000 gallons. Each division can be used as a single reservoir for itself, while the other may be emptied for inspection and repair.

At the influx of the aqueduct at 85th street, west side of the reservoir, the street-level is equal with the top of the embankment. All the other parts of embankment had to be carried up more or less in order to reach the top, the ground being lower; and at efflux of the reservoir in 80th street, east side of the reservoir, it is 38 feet below the top.

All the embankments are of earth, the interior puddled with clayish earth or loam. The sides on the streets and avenues are protected by dry walls of stone, their outside being laid in lime-mortar and the joints pointed, Figs. 127 and 128. The inside slopes of the embankments washed by water, are protected by a dry stone pavement of 15 inches thick. At the bottom of the reservoir the bare rock or earth is left without any artificial contrivance.

In order to keep the surface of both the divisions at a level, a connecting or communicating-pipe, Fig. 125, has been placed, of which Fig. 123 is the section; the pipe is bedded upon rock, surrounded and supported by concrete: halfway a stop-cock is put for shutting and opening the pipe; over this cock a circular well is erected, and carried up to the top of the embankment. Upon the top of the well two caps are placed, on which a nut is screwed, like that at Fig. 94, *i*; by means of which, in connection with the screw-bar, the stop-cock can be drawn and shut.

When the water has reached its height in the reservoir—viz. 4 feet below the top of embankment—and the rising still continues, the surplus water falls by itself into the waste-weir well. Through the same way 3 feet more water can be drawn off from the surface when required, by taking out the timbers. Over the top of this waste-weir well, a bridge with a brick arch is erected, for the passage on the top of the division-embankment.

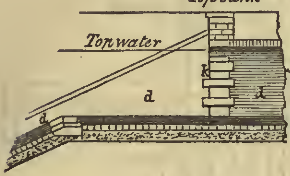
The influent-gate, Figs. 120 and 121, receives the water from the aqueduct *a*, by the gate-chamber *b*, and lets it either directly by the gateways *e e e* over the sluice-channel *c c* into the northern division, or by

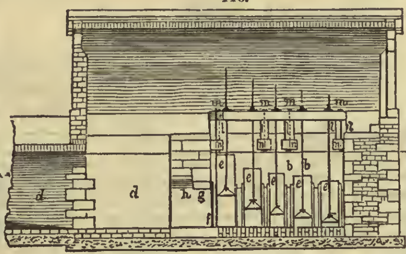
the gateways *f f f* through that part *d d* of the aqueduct which is built in the body of the western embankment leading into the southern division. The various apertures of the gateways of the two entrances are separated from each other by means of jambs of cut-stone 9 inches thick, covered over at the front, in the gate-chamber, with stone lintels, Figs. 116 and 119, at *g g*; in the rear at *h h*, however, the passages are arched over with half a brick, Fig. 119. The gates, with their frames, are made as shown at Fig. 97; the gate-caps rest partly in the walls and partly upon the posts *l l*. In order to prevent their rising, in screwing the gates, consols *n n* are projected, to which the gate-caps are secured by the bolts *n m*. By those two sets of gates, the water-influx to the divisions of the reservoir can be regulated completely.

Over the whole a stone building arched with brick has been erected, and covered with flags of grey wacke.

116.

117.





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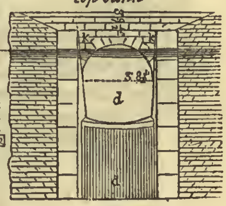
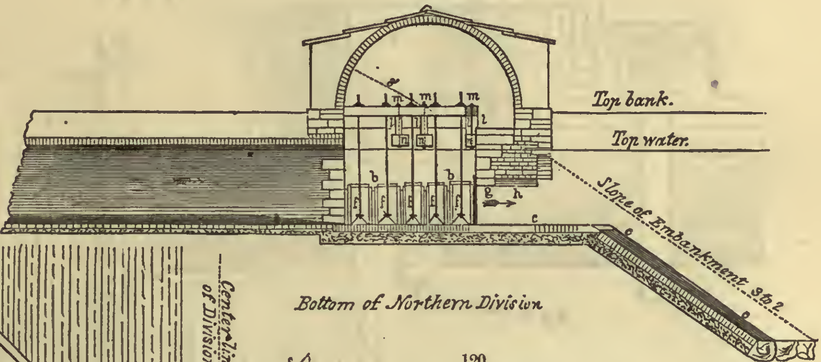
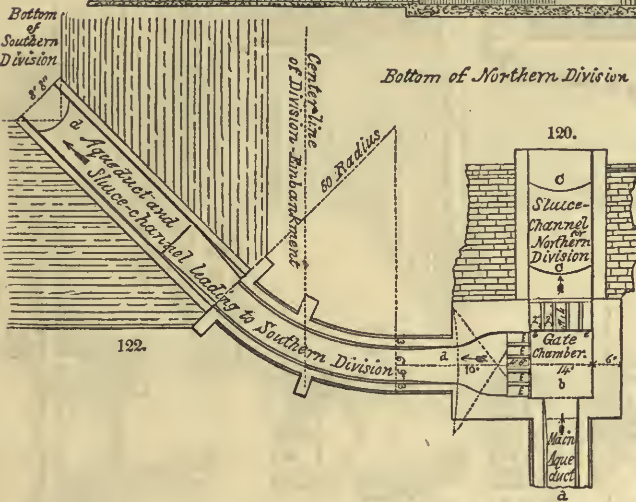


119.

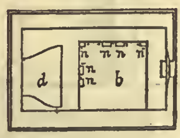


120.



122.

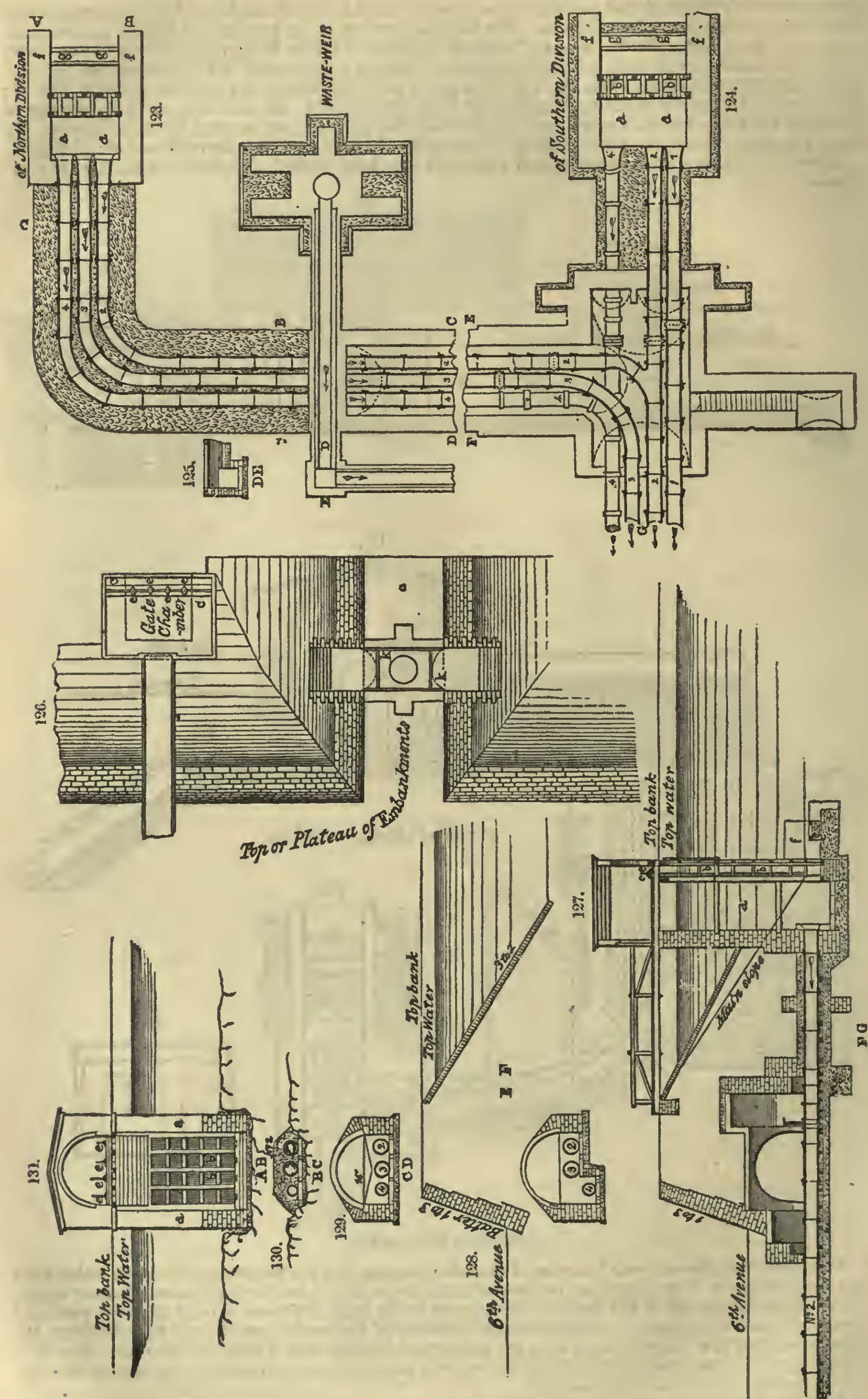
121.



Scale.—1 inch = 40 feet.

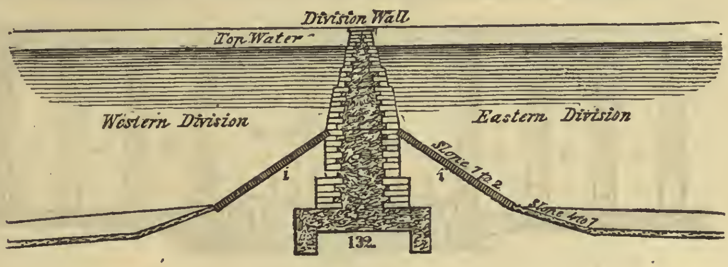
The efflux from the reservoir is arranged in such a manner, that the water may be drawn either from the one division or from the other, or from both at once, each division having its own separate outlet. Three pipes, coming out of the northern division, run in the body of the eastern embankment, protected by a vault built in the same. At the southern extremity of the vault, upon the axis of 80th street, the pipes are united to 3 others, leading from the southern division, making 4 after the junction. Nos. 1, 2, and 3, carry the water to the distributing reservoir for the lower part of the city; No. 4 is for the supply of the east side of the upper town.

The arrangement of efflux is thus. *a a a*, Figs. 123, 124, 126, 127, and 131, is a tower, erected with substantial stone walls; in the open side, fronting the reservoir, is put the gate-framing with the screen *b b*,



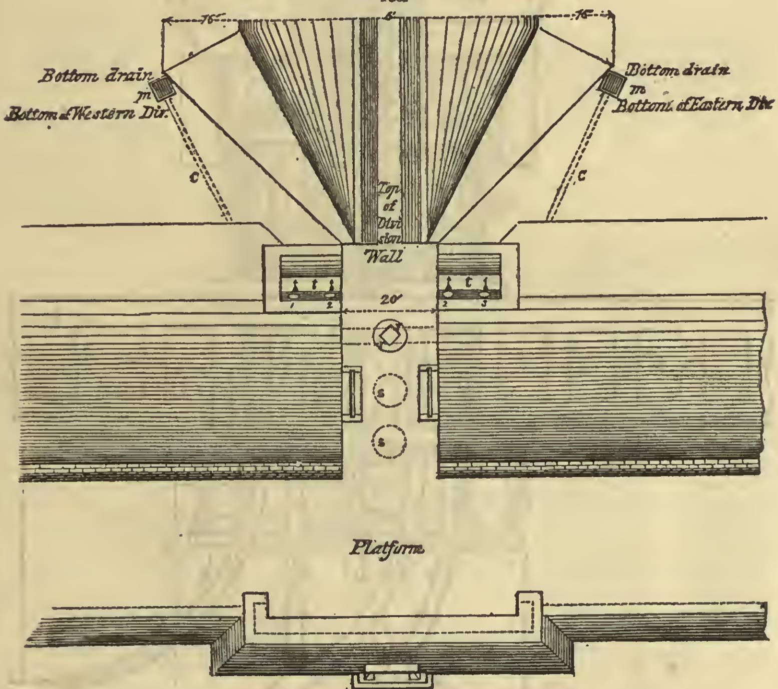
SCALE.—' inch — 40 feet.

the same consists of two frames, of 1.2-inch white pine timber; the outer is filled with 1-inch oak slats 6 inches wide, put 1 inch apart, Fig. 131; the upper part is covered with plank; the inner, or 2d frame, is left open as far as the just-mentioned planking reaches. Below this the gate-apertures are left—4 of such are in the tower, Figs. 123 and 127; at the tower, Fig. 124, they are of 2-inch pine plank, connected by pieces of plank nailed across and slid in wooden grooves; some of them are opened by sliding down, some by sliding up. Opening and shutting is effected by iron rods reaching up to the gate-caps *c c c*, Figs. 126, 127, and 131. On the top of each rod a screw is cut, which goes into the nut put upon the gate-caps; the nut and screw are shown by Fig. 93, at *d e* and *i*. Above this gate and screen-frame the tower is carried higher up and roofed over. Fig. 131 is the elevation of the tower-pavilion; Fig. 127, its section, and longitudinal section of bridge connecting the tower with the embankment. In the interior of the tower, Fig. 127, some timbers are put for support of the gate and screen-framing when the gates are



132.

133.



42.d Street.

SCALE.—1 inch = 40 feet.

exceed. At the figure named, *f* shows the wing-walls of the tower, and *g* a breast-wall, being carried up against the bottom of the reservoir. Although Fig. 127 here is the section of Fig. 124, just as Fig. 131 is the elevation of Fig. 123, yet the arrangement and construction of the two are alike, except in some dimensions, which at Figs. 123 and 131 are smaller.

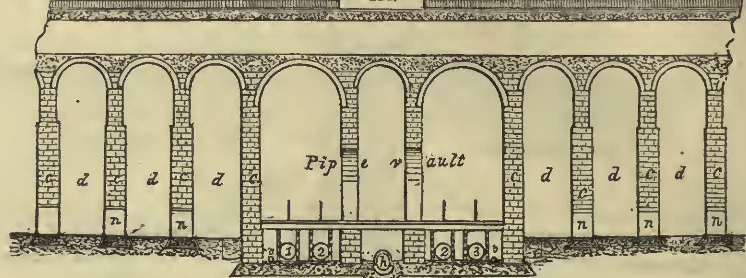
In the rear-wall of the tower are the mouths of the pipes; the latter for some distance are bedded in and covered over with concrete, Figs. 123, 124, and 130. When the pipes Nos. 2, 3, and 4, coming from the northern division, have passed the line of the waste-weir sewer, D E, Fig. 123, they enter into the pipe-vault, Fig. 129 and Fig. 128; here they join with the pipes Nos. 1, 2, and 4, and so pass on. The letters *h h* show the stop-cocks; at *i* is a passage with stairs starting down from the avenue. In order to prevent all sudden opening and shutting of the stop-cocks or sliding-valves, consequently the pushing

of the water, and to obtain a water-tight sit, a set of conical wheels and the crank, Fig. 98, were put in connection with the stop-cock.

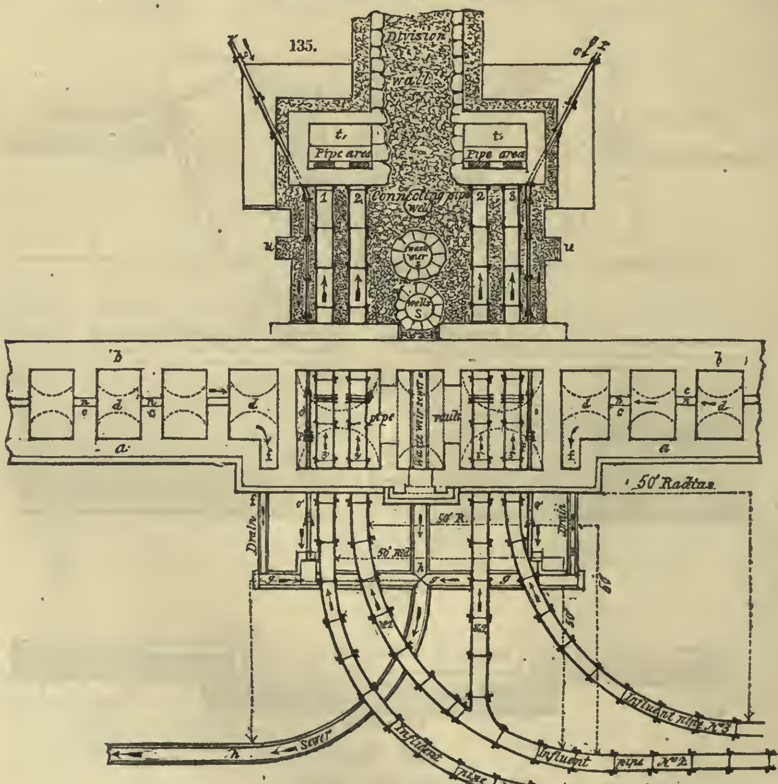
There are for the supply of the upper town, at the west side of the reservoir, two other effluent-gates, of similar description and equal heights with the corresponding ones in the same reservoir-division; yet they have their outlet through one pipe only. They are, together with the towers, of smaller dimensions in length and width.

The Aqueduct-Line continued.—From the mouth of the pipes at the 6th Avenue, the aqueduct, consisting here of three pipes, 36 inches each, 4 feet under ground, runs along 80th street, bends round the corner into 5th Avenue, proceeds here a distance of 2.176 miles across three depressions of ground and two

134.



135.



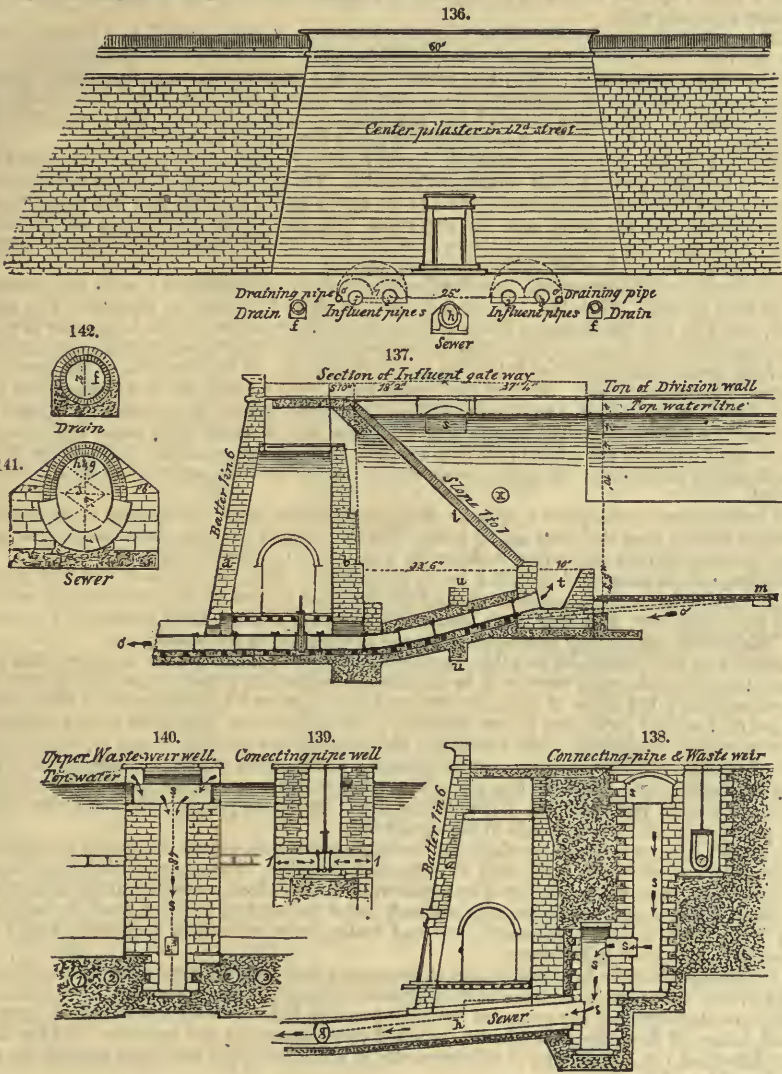
Scale.—1 inch — 40 feet.

heights. On the summit of the latter air-cocks are put, to allow the air to escape. At the lowest points of the depressions there are outlets, in order to get rid of the sand which might collect here.

The Distributing Reservoir is also divided into two divisions, an eastern and a western, by means of a division-wall. Each has a separate inlet and outlet, and may be used as a reservoir for itself, while the other division is emptied. It is erected on the top of Murray hill, the greatest part being above ground; as for instance—the corner marked by *x*, is 49 feet above the street; *y*, however, only 39 feet.

The outer walls *a a* of the reservoir, of 4 feet thickness, the inner of 6, connected together with the cross-walls *c c*, 4 feet thick, form the chief mass of the enclosure of the basin. The cellules *d d*, between the cross-walls, are arched over 12 inches thick with bricks; their spandrels, of some feet in height,

backed with stone masonry; then filled over and levelled off with concrete to a height of 6 inches above the highest point of the extrados of those brick arches. The division-wall is of concrete, faced with rough stone-masonry, Fig. 146. The bottom of the basin is puddled with earth, over which a course of concrete, 12 inches thick, is laid; the sides are puddled, and slope up 1 foot in 4, horizontally, for 16 feet in width; then 1 to 1 to the coping of the enclosure. The lower part of this slope is covered with a course of concrete, 12 inches thick; the steeper upper part is protected by a pavement 15 inches thick, laid in hydraulic mortar. The slopes of the division-wall have the same protection. The upper-filling of the cellule-arches is likewise of puddle, except 2 feet next the slope-pavement, and 2 feet below the flagging of the platform, Figs. 134, 137, 138, 144, 150, and 151, which will prevent the frost from penetrating into the puddle in parts not covered with water.



Scale.—1 inch = 40 feet.

The total length of the entire structure, measured at the top of the cornice, (not in its projection,) is 420 feet; so the width. The basin is 386 feet square, 42 feet deep, and when filled with water 38 feet, contains 21000000 gallons. In order to collect and drain off any water which might filter down through the embankment *i*, and through the walls *b b*, there are left in the cross-walls *c c*, small openings *n n*, Figs. 134, 135, 143, 144, 150, 151, by which the water may drain from cellule to cellule without the structure. Out of the northern side, the drain-water runs through the two sewers *f f*, Figs. 134, 135, 136, 141, 142, through the receiving-sewer *g g*, to the street-sewer *h h*. The southern part of the structure makes its drainage in an opposite direction—viz. through the drain-sewer *i* to the well *k*, Figs. 134, 135, from which it is carried off by the street-sewer of 40th street. Fig. 140 shows the lon-

gitudinal section of the sewer q, the cross-section of the well k, with the mouth of the street-sewer l, the construction of which is given by Fig. 139; the sewer $i\,i$ has a like construction as Fig. 142.

In order to draw off entirely the water from the bottom of each division, when required for cleansing or repairing them, 2 little wells are put in, $m\,m$, Figs. 133, 137, and a slight descent of the bottom towards them, from off all sides, arranged. In those wells the last of the contents collect, and is drawn away by pipes marked $o\,o$ in the above-mentioned figures. The pipes discharge the water into the receiving-sewer $g\,g$; by the stop-cocks $p\,p$, those pipes can be opened and closed.

In order to keep the water of both divisions on a level, a 36-inch connecting-pipe is put through the division-wall. Fig. 135 shows the ground-plan of the well in dotted lines. Fig. 133 is the top of the well, with a square opening formed by jutting over the coping-stone. Fig. 139 is the longitudinal section of pipe, stop-cock, and well.

For letting out from the reservoirs the superfluous water, a waste-weir well, in 2 descents, or for 2 cascades, has been constructed in the body of the division-wall. That water which falls from the opening of the bridge $s\,s$, Figs. 132, 137, 138, 140, covering the first well, fills the water-bag below, which is 8 feet deep; it passes through the opening s, makes then the second fall down the well s, fills its water-bag, and is carried off through the sewer $s\,h$ into the street-sewer of 42d street. The construction of the sewer h is shown by Fig. 141; it has here, as well as in g, a bottom and arch of stone.

The pipes 1, 2, and 2, 3, having made their curves running parallel with each other, they end in the pipe-areas $t\,t$, and the aqueduct itself terminates herewith. The just-mentioned figures show the course of the pipes: Figs. 136 and 140 the cross-section of the course at the entrance into the structure of the reservoir; and Fig. 134 the parts near the stop-cocks. Fig. 137 is their longitudinal section and section of the pipe-area: the same figure shows also the bedding and wrapping of concrete round the pipes in the embankment; it exhibits also the cut-off wall u.

For the effluence of the water into the distributing-pipes, an effluent-tower v, with gate-frame w, is erected for each division. Figs. 143, 145, show the ground-plan; Fig. 146, the elevation; Fig. 150, the side-view; and Fig. 151, the section. The gate-frame has a screen at the outside, in the rear of which is the gate-frame itself; both are supported by a breast-wall, over which the water falls upon the interior bottom of the tower, which is 8 feet below the top of that wall. In the rear wall of the tower is put the entrance into the city-main. Each of the towers has a pipe x and z, which are connected in the pipe-vault by the cross-pipe y; x runs to the eastern part of the town, z to the central part, and $t\,z$ to the west part, for distribution. The ground-plan shows the way in which all 3 pipes can be supplied by the one set of gates, or the other, or by both together. The arrangement for the outflow of water answers, therefore, completely, the purpose—to empty the one division, entirely, while the other remains filled.

At the lowest points of the pipes x, y, and z, draining-pipes with stop-cocks are put in, to let out into the sewer-pit $k\,k$ any sand that may collect here. The way to work the gates from the caps, as well as the upper structure of both the towers, is shown by Figs. 145, 146, 150, and 151.

The platform of the reservoir is guarded by an iron railing. At the elevation of 119 feet above the level of the sea, it commands a complete view of the west and east of Manhattan Island, as well as of the south part of the city, with New York bay, and at a greater distance in that direction, the Atlantic ocean. This view is exceedingly beautiful, and is one of the finest in the world.

Distribution of the Water.—From this reservoir, the distribution of the water is made. The above-mentioned three 36-inch pipes convey it to the lower town, which is built closer and closer the further down one goes; 134 miles of pipes of all sizes, between 36 and 4 inches, conduct it through the streets, and feed several public and private fountains; these pipes are laid down in the centre of the streets, or as near so as possible. The branchings and crossings are made by means of single or double sleeves cast together with a main-piece. The pipes are put together with faucet and spigot, 6 inches deep; at the smaller pipes, 4 inches. The pieces have a length of 9 feet, each piece making thus 9 feet run of water-conduit when put together. Before laying down, they were proved with the hydraulic press, with the pressure of 200 to 250 pounds to the square inch.

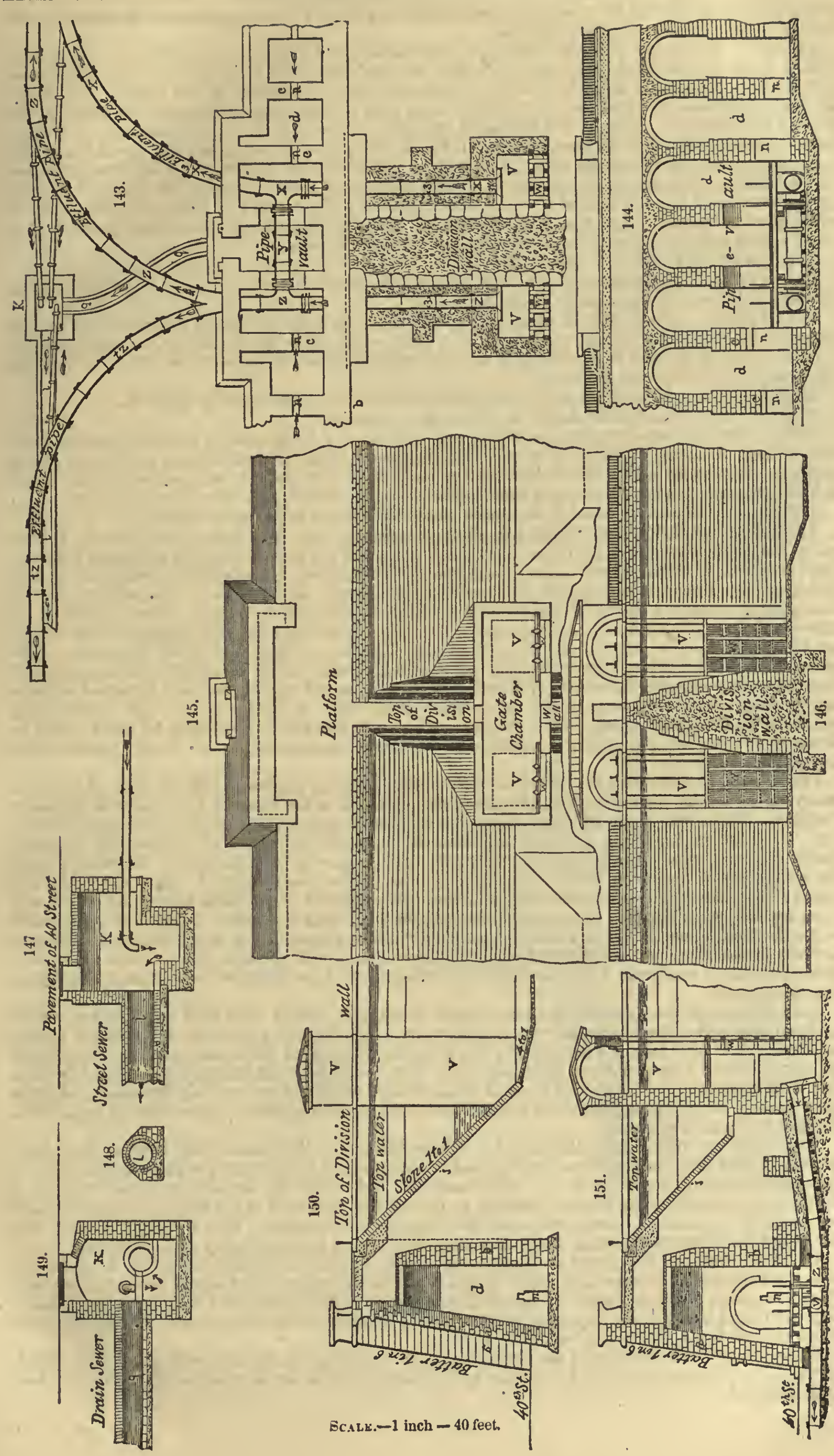
At the corners of streets where crossings and branchings occur, stop-cocks are put in, in order to cut off districts of pipes, when this is required for alteration or repair. Those pipes that run off from the street pipes, leading into the houses, are ½ to 1 inch wide, made of lead, connected to the main-pipes by boring. Such a house-pipe has either a mouth-cock under the outdoor steps, or leads to the kitchen, which in this country is in the basement. To feed bathing-tubs or bathing apparatus, a pipe sometimes rises to the upper-story bedrooms.

Pipes branching off for the hydrants, placed at convenient distances, are for the most part of cast-iron, branching off from the mains by sleeves; at the larger-sized pipes, by means of boring. The hydrants, as far as they are above ground, are protected by a cast-iron case to keep off frost, heat, and damage. For the extinguishing of fires, the engine-hose is screwed to the muzzle of the hydrants. At the harbor, pipes are branched out, terminating at the bulwarks, in order to supply the ships, and fill the water-casks on board by a hose.

The cost of this aqueduct amounts to 8575000 dollars, including purchase of land required, extinguishing of water-rights, and some unfinished works. This amount is within 5 per cent of that estimated by the chief engineer, Mr. John B. Jervis, and the percentage occurs chiefly below the estimate. To this is added 1800000 dollars, the cost for the distributing-pipes.

The first two millions had to be raised at an interest of 7 per cent, and are payable from 1847 to 1857. For the rest, 5 per cent is paid, and to be redeemed from 1858 to 1880. 647157 dollars was the discount for issuing the loan, which, together with the interest paid already during the construction of the work, brings the total expense to 12500000 dollars.

The annual interest for this capital amounts to 665000 dollars, which is collected by a direct water tax, and some indirect taxes; by means of an existing sinking fund, the capital will be redeemed by degrees. The water-tax amounts to 10 dollars for a house of middle size; manufacturers, hotels, bathing



SCALE.—1 inch — 40 feet.

establishments, distilleries, livery-stables, bakeries, sugar-refineries, breweries, slaughter-houses, etc., and ships, pay according to extension and size.

ARCHES. Arches are of various shapes, as Pointed, Elliptical Segmental, and Circular. The outer surface of the arch is called the *estrados* or back of the arch, the inner or concave surface, the *intrados*, or the soffit; the joints of all arches should be perdendicular to the surface of the soffits. The stones are called *arch stones* or voussoirs. The first course on each side are termed *springers*, which rest on the imposts or abutments. In case of a segmental arch, the course beneath the springers are called *skew-backs.* The extreme width between springers is called the *span* of the arch, and the versed sine of the curve of the soffit, the rise of the arch. The highest portion of the arch is called the *crown*, and the centre course of voussoirs the *key-course.* The side portions of arches between the springing and the crown, are termed *haunches* or flanks. All arches should be well sustained by backing on the haunches called *spandrel*-backing. The line of intersection of arches cutting across each other transversely is called a *groin* and the arches themselves *groined arches.* See Bridge.

ARCHIMEDEAN SCREW. See Screw.

ARCHITRAVE. The lower of the three principal members of the entablature of an order, being the chief beam resting immediately on the column.

ARCHIVOLT. A collection of members in the face of an arch, concentric with the intrados, and supported by imposts. *Archivolt* of the arch of a bridge—the curve line formed by the upper sides of the arch-stones in the face of the work; it is sometimes understood to be the whole set of arch-stones which appear in the face of the work.

AREOMETER. An instrument for measuring the density or specific gravity of fluids.

ARGAND BURNERS AND LAMPS. See Gas and Lamps.

ARRIS, the intersection or line, on which two surfaces of a body forming an exterior angle meet each other. Although the edge of a body may in general mean the same thing as its arris, yet, in building, the term arris is restricted to those two surfaces of a rectangular solid, on which the length and thickness may be measured, as in boards, planks, doors, shutters, and other framed joinery.

ARTESIAN WELLS, so called from a mode practised in Artois in boring for water.

ARTESIAN WELL OF GRENELLE, *Boring Apparatus of.* About the year 1824, M. Péligot, one of the superintendents of the hospitals at Paris, suggested the idea of sinking a well upon the Artesian principle, and workmen were sent from Artois for the purpose; whilst this was being effected, M. Mulot, a smith, became interested in the operation, and turned his attention to the subject; he was consequently employed by the Marchioness de Groslier to sink one at Epinay; success attended his efforts, and he was nominated to attempt one at Grenelle. The primitive soils, according to M. Arago, are but rarely stratified, or are found in regular beds. The fissures in granitic rocks, the crevices separating the contiguous masses, have but little width or depth, and do not frequently communicate with each other; in such soils the waters of filtration have but limited outlets, each film or thread terminating its course alone, without receiving any increase from others in their descent. The springs being numerous in the neighborhood, it was not thought probable that any vast quantity of water could be obtained, as the whole of the rain penetrating the earth was supposed to pass off through various openings in the sides of the hills.

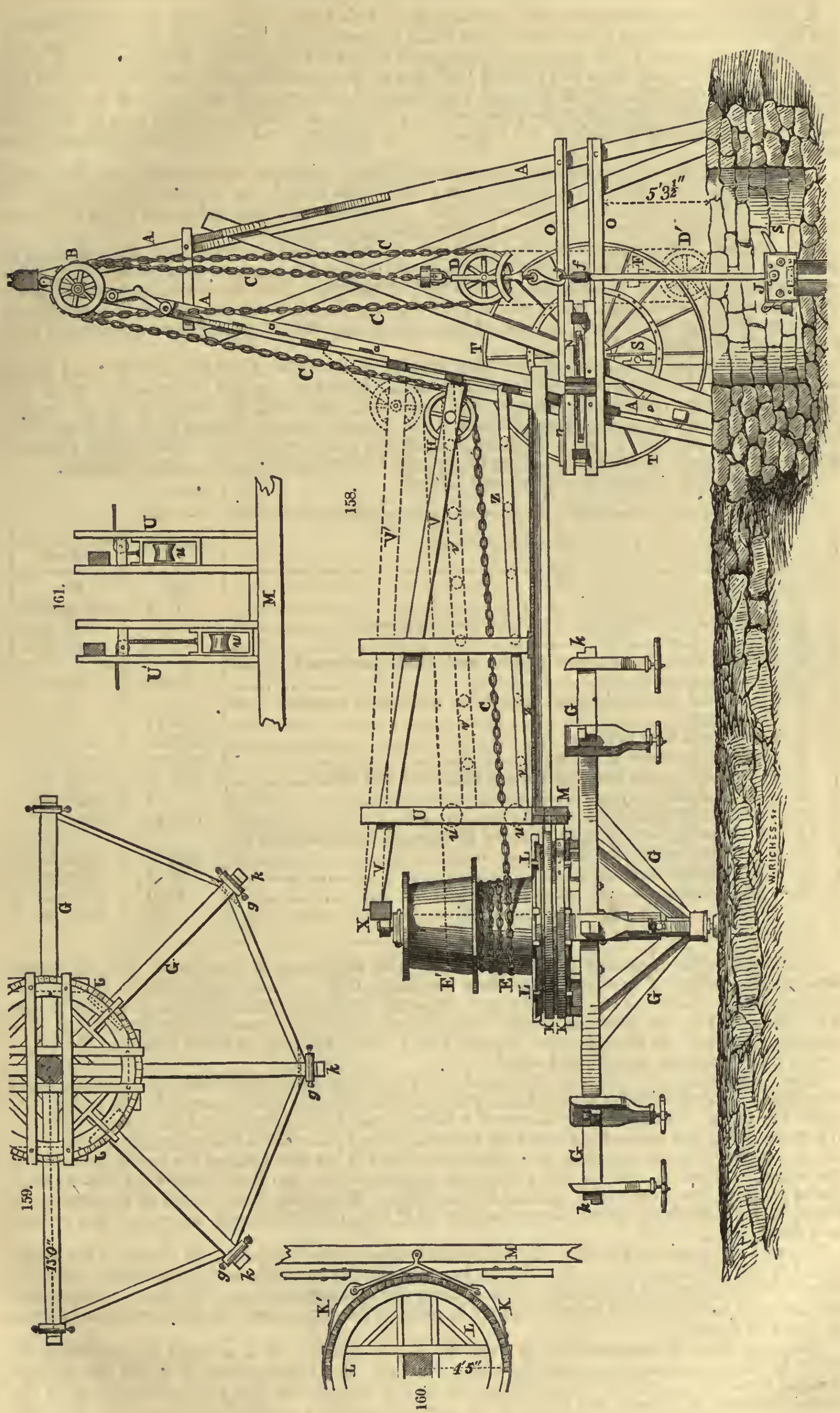
The secondary soils, which are composed of a variety of rocks, in general take the form of immense reservoirs or basins, the centre being considerably depressed, or the extreme boundaries of it greatly elevated. Within this basin, hills, and often mountains, arise, apparently destroying its original character. The stratification of the secondary formation is in regular beds, some of which are of enormous thickness, composed of sand or grit, and very permeable; these permeable beds, as they rise towards the extremities of the basin, become bare on the sides of the mountains and hills. The rain-water which falls on the earth, after penetrating it, forms one continued sheet, which pursues its course with great rapidity when the beds have a great declivity, and, reaching the lowest point, is accumulated in vast quantities. One chalky or calcareous stratum, which is furrowed out in all directions, and particularly in the upper portion, allows the pluvial water to pass with great facility, and also to circulate through the mass to a great depth: and in this peculiar stratum the wells both of Grenelle and Rouen have been bored.

The tertiary soils are stratified, and composed of many beds placed over each other, and separated by clean and well-defined joints, like the secondary, on which they rest; these basins are of less extent, and derive their form from the rectifying of the beds, the elements of which they are constituted being the same as those found on the neighboring hills. The several beds are arranged in a regular manner, and their separation is formed by a layer of sand, through which the water freely percolates; in these several sandy fissures it acquires force as it descends, and at great depths, its pressure being augmented, the flow is rendered constant.

These soils are undoubtedly the best for sinking Artesian wells, because they have at their base courses of sand lying on impermeable clays, and are less subject to dislocation or rupture than rocks of the older formation. Such strata are easily examined, and are usually found rising from the centre of the basin, and following an inverse direction to that of the inclination of the water, which, like a subterranean river, pursues a downward course till it meets with an outlet. They frequently become broken, when the water they contain weeps into small rivulets and is carried away on the surface.

Where the well has been bored at Grenelle, the upper stratum or tertiary deposite is 41 metres in thickness; the next is composed of chalk mixed with flint, 99 metres; then a gray chalk, without any silex, 25 metres; to this succeeded a gray chalk, in which were iron pyrites, 341 metres; then a wealden clay, gray sand, and a sandy clay, in which were found ammonites and other fossils; the whole depth bored through being 548 metres, or about 1798 feet.

Before giving the description of the apparatus used in boring this well, we will give a short sketch of the difficulties encountered and overcome by M. Mulot, to whom the direction of this great work had been intrusted.



158. 159. 160. 161.

M. Mulot commenced boring in 1833; he easily pierced the tertiary sands, which are at Grenelle 13C feet thick, but shortly after having reached the chalk, at the depth of 377 feet, the sides gave way and filled the bored space, which was cleared again, after fifty-seven days' labor; this happened in June, 1834. In May, 1837, the borer had reached 1246 feet, when the valved-spoon, together with a rod 262 feet long, fell to the bottom of the hole and were shattered to fragments; the weight of the mass was 100 cwt. Many contrivances were proposed—some even put in execution—but in vain, till M. Mulot had the idea of wearing the ends of the fragments, and thus extracted them, fifteen months after the accident.

In April, 1840, the instruments were wearing out rapidly, while they were making little headway through the hard chalk, when, being raised to a considerable height, the boring-screw fell, and was buried in the compact rock to the depth of 75 feet. It became necessary to bore all round it in order to free it, and after many months of labor this new obstacle was surmounted.

In December, 1840, the spoon detached itself from the rod, causing a little delay in the operations of M. Mulot, who bored a hole in the sides of the well and pushed the separated instrument into it. This was the last impediment to overcome, and the 26th of February, 1841, the rod suddenly sunk several feet; immediately a column of warm water 1797 feet high, equal to the pressure of 53 atmospheres, rose from the bosom of the earth, and poured upon its surface 800,000 gallons of water, having a temperature of 79 Fahrenheit.

But, besides boring, it was necessary to give support to the sides of the well, which would fall in, unless composed of material more consistent than earth. A tube of a certain calibre is first introduced, then another smaller one slipped within the first, and so on; but should the boring be deeper than expected, it would become necessary to withdraw these tubes in order to replace them by larger ones, because the last must be of sufficient calibre to allow the rod to work. At Grenelle it was necessary to draw off five series of tubes, and to bore larger holes to introduce tubes of a greater diameter.

The following is a table of the strata bored through.

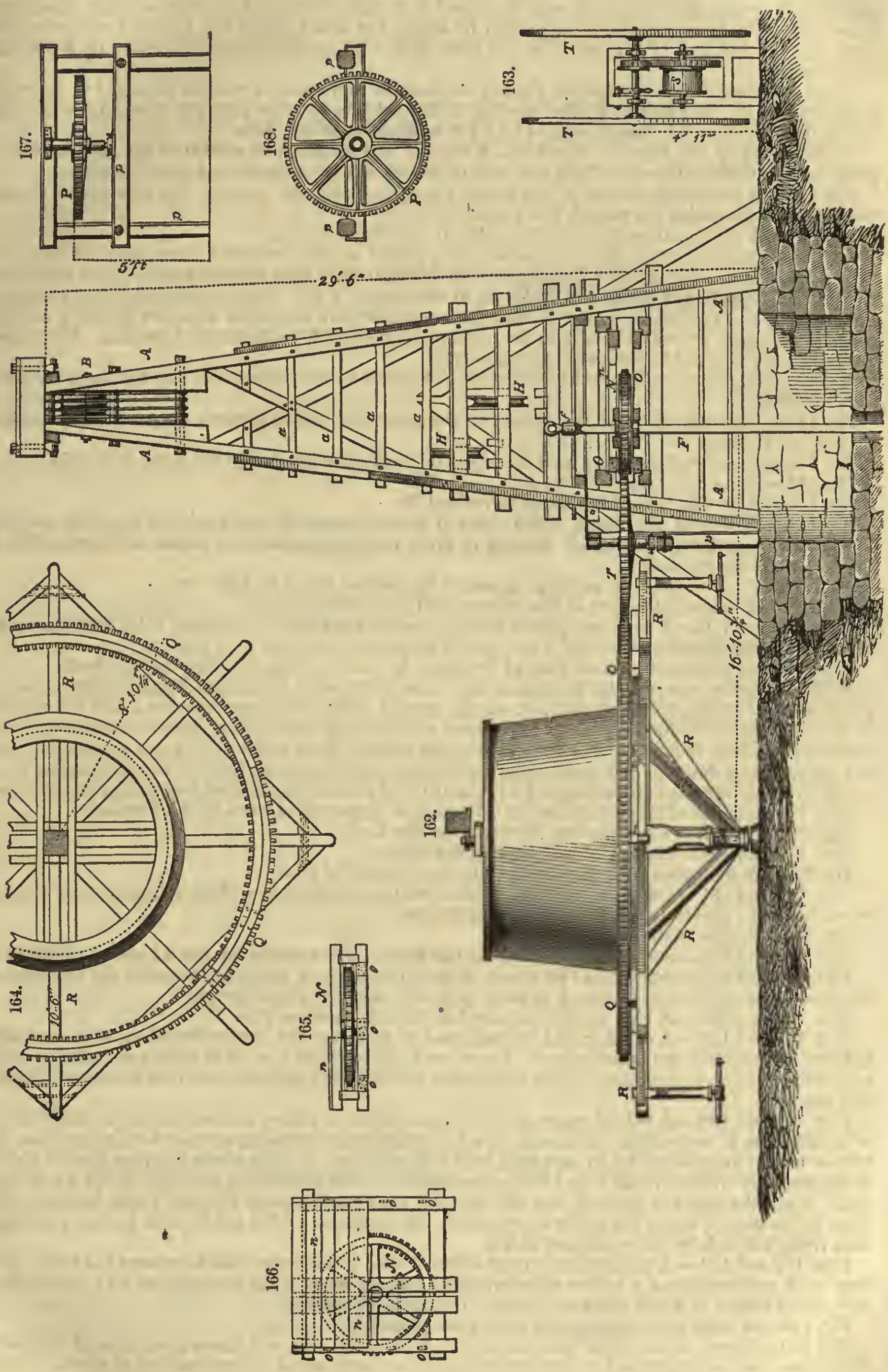
	Nature of the Strata.	Thickness.	Depth beneath the soil.
		Feet.	Feet.
1	Foundation of a basin	7.21	on the surface
2	Alluvial soil, composed of rolled flints and gravel	24.40	7.216
3	Chalk	2.78	31.652
4	Plastic clay, lignites, iron pyrites, and sand, penetrated by sulphuret of iron	65.69	34.44
5	Marl and calcareous sand, containing nodules of compact limestone	36.11	100.13
6	Chalk and silex in lumps	312.89	136.25
7	Hard gray chalk with silex	652.92	449.14
8	Gray chalk, very hard, alternating with more soft chalk	423.18	1104.23
9	Green chalk	.98	1524.20
10	Blue chalk with clay	101.73	1526.0
11	Black and blue clay, with strata of green sand, containing iron pyrites and fossils	101.79	1658.51
12	Argillaceous sand	2.30	1780.28
13	Green sand	4.50	1792.57
	Water		1797.47

Description.—The apparatus consists of a crane with four beams A, iron-bound. At the summit there are four pulleys of cast-iron B, on these the chains C pass; these chains also go through two other moveable pulleys D D′. The chains C, attached by one end to the guide-strap of the pulleys D D′, are hooked by the other extremity on the conical drum E E′, around which they are wound in opposite directions. By these pulleys the iron bars F, 26.24 feet long, to which are attached the burrowing instruments, are lowered and raised.

To raise the rods, eight horses are harnessed at G, Figs. 158 and 159, which being set in motion, one of the chains passing through the pulley H coils round E, while the other chain is unrolled. The pulley D, to which the rod F is suspended by means of a hook, is raised, and brings up all the boring apparatus. When this pulley has reached the top of the crane the second pulley D′ is made fast; then the bar just raised is taken off by men standing on *a*; the hook is fixed to the next bar, and the horses are driven in the opposite direction. While the pulleys are exchanged, the top bar is seized by the crank J, placed at the orifice of the well to prevent it from falling. The cranks J are formed of two strong iron plates, between which are set two eccentric chaps J^1 J^2, which allow the rods to ascend, but prevent their falling back.

One man is necessary to lower the rod, which is accomplished by pulling or loosening the break, Figs. 158 and 159, at pleasure. This double break consists of two large hoops K K′, surrounding the drum L, which is covered with a thick sheet of iron; one of the extremities of the hoops is fastened to the horizontal beam M, while the other is kept in place by a square placed out of the works, and opened or closed by a lever.

The next thing to be considered is how the rod is turned. It is adapted to the wheel N, which is made to communicate with the wheel, Fig. 163. The toothed-wheel N, is for this purpose changed from the position it occupied, Fig. 158, to that represented Fig. 162, corresponding to the axis of the well; a square hole is made in the centre to receive a square bar of iron .2624 of a foot


162.
163.
164.
165.
166.
167.
168.
29'-6"
16'-10¼"
4' 11"
5 ft
8'-10¼"
10'-6"

square and 13 feet long, which is adapted by one extremity to the boring-rod, and by the other is suspended to the hook of the pulley D. When the wheel N is fixed to the rod it is adapted to its intermediate toothed-wheel P, fixed to a wooden frame close by the crane. The wheel P is put in connection with the great wheel Q, placed over the wheel R, to which two, and sometimes three horses are harnessed. The burrowing-rod is suspended by chains run into a ring *g*, Fig. 159, and coils round the drum S, Figs. 158 and 163′, situated on the other side. The wheel T serves to raise or lower the instrument.

When the wheel R is put in motion, the rod receives the movement of rotation imparted to N by the toothed-wheel P. The men at T allow the rod to descend slowly. The pulley D′ would be in the way during the operation, it is therefore fixed by a pin to the links of the chain.

Explanations of the Figures.—Fig. 158.—A vertical and longitudinal section of the apparatus in a plane passing through the axis of the well, and of the wheel used to lower and raise the borer.

Fig. 159.—A horizontal section of the wheel G, made above the breaks; the two conical drums around which the chains are wound, being omitted.

Fig. 160.—A horizontal projection of the drum L, and of the breaks.

Fig. 161.—A front view of the two frames U U′, placed in the horizontal beam, near the wheel G. Within these frames two smaller frames are made to slide; they have wooden rollers, *u* and *u′*, and are intended to support and guide the chains C, to the drums E E′. These chains, when slack, rest on the rollers *v v′*. The frames U and U′ have their superior part in contact with the beams V and V′, which are fastened by one extremity to the crane, and by the other to the strong bearer, X. The pillow of the axis of the wheel G, rests also on this bearer.

A flooring, Z, connects the wheel to the crane, and places within the reach of the workmen the parts just described.

Fig. 162.—Vertical and transverse section of the apparatus, whose plane is perpendicular to that of the section, Fig. 158.

Fig. 163′.—A view of the drum used for supporting and lowering slowly the borer as it sinks.

Fig. 164.—Plan of the wheel R, Fig. 162.

Fig. 165.—A profile view of the frame and wheel N.

Fig. 166.—A plan of this frame, which slides in grooves made in the beams O, Figs. 158 and 162, on small friction-rollers. The small flooring *n*, gives passage towards the centre of the wheel N, in order to adapt the rod in it.

Fig. 167.—Front view of the wooden support to the toothed-wheel P, Fig. 162.

Fig. 168.—A horizontal section of this support, and plan of the wheel.

Figs. 169 and 170.—A front and profile view of one of the moveable pulleys, D D′, with its guide-strap, giving attachment to the hook *d*, to which is suspended the borer by a ring.

Figs. 171 and 172.—An external view of the crank J, with a section following the line 1—2.

While the boring goes on, this is set over the orifice of the hole; to this end, two semicircular pieces *j′* are attached to the plates J, and rest on the ground. The rods pass between J and the nippers J^1, J^2. As long as the rods are raised the nippers yield; but as soon as they remain motionless, either to change the rods or for any other motive, the arcs through their eccentricity press against the bars and prevent their descent. To secure them further, their other sides are held by the force-screws j^2.

Fig. 173.—A fragment of galvanized iron tube, 0.016 of a foot thick, used as a conductor to the water.

Figs. 174 and 175.—Pincers used for the extraction of fragments of wood or other matters.

Fig. 176.—Section of the foregoing, following the line 3—4.

Figs. 177 and 178.—Pincers for withdrawing the tubes.

Fig. 179.—A horizontal section of a branch in the direction of 5—6.

Figs. 180 and 181.—Details of an instrument called Caracol, used to withdraw fragments of the rod when they have penetrated into the parietes of the well.

Fig. 182.—A plan of the instrument.

Figs. 183 and 184.—Screwed rods composing the borer. The superior bar has a hook also vised to it.

Figs. 185 and 186.—Rods united by means of pins, the heads of which are buried in the thickness of the bars. The end of one is fissured, in order to receive the end of another rod.

Figs. 187 and 188.—A ring which is attached to the rods by three pins.

Figs. 189 and 190.—A chisel, called Trepan, used to perforate the hard rocks which it is necessary to break and to crush at the same time. There are three edges, *a*, *b*, *c*. The edge *a* is double, *b* and *c* are turned in opposite directions. This implement will cut the rock and crush it in whatever direction it is turned.

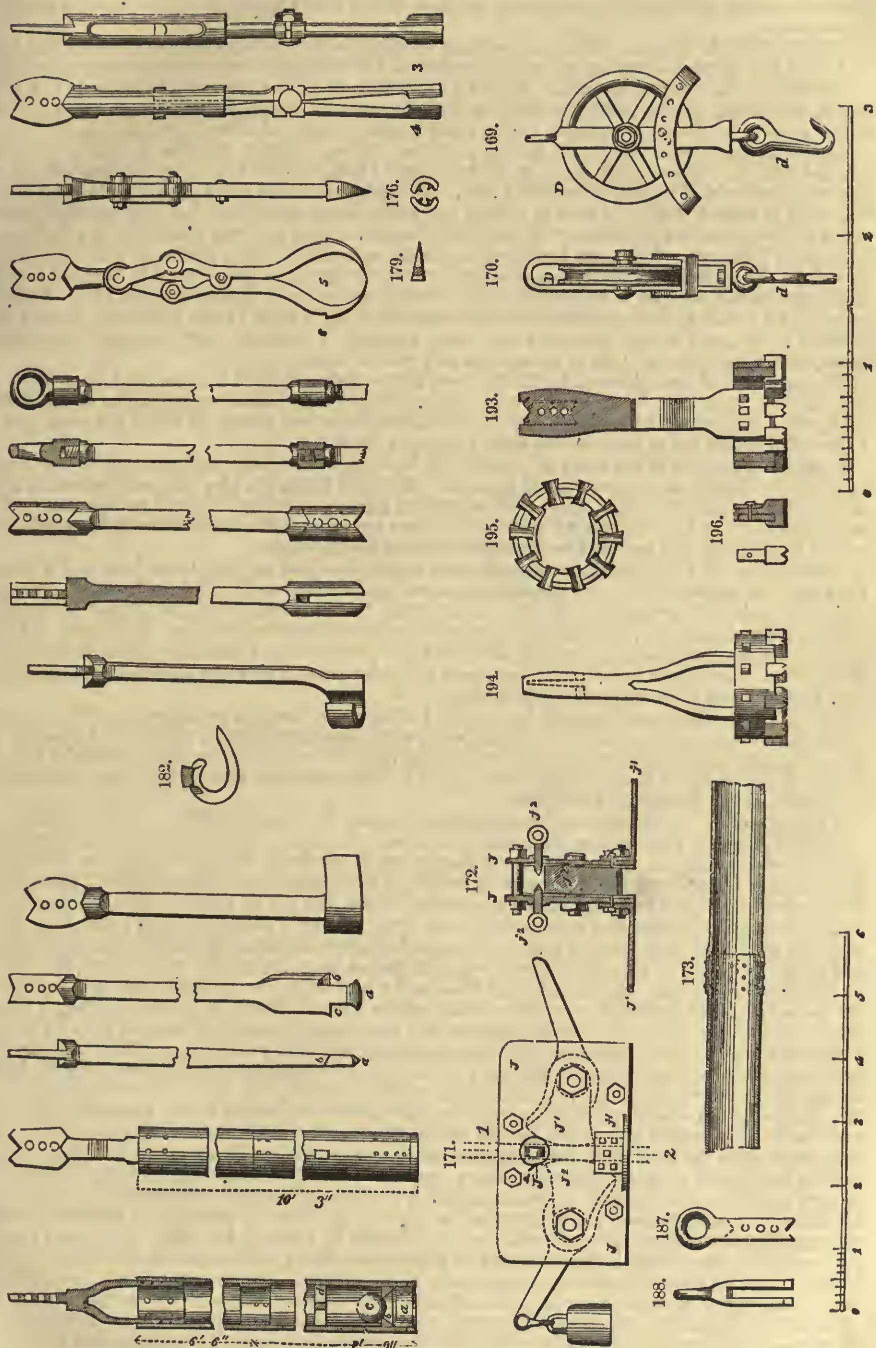
Figs. 191 and 192.—A valved spoon, used in sands and clays almost rendered liquid by the water in which they are in suspension. It consists of a long cylinder in sheet-iron, open at both extremities, the inferior being strengthened by an iron ring with a sharp edge. A little above this ring there is a disk, at the centre of which a round hole has been perforated. This opening is perfectly closed by an iron ball. When the spoon is lowered into the hole the sand pushes away the ball, which, however, falls back by its weight, closes the orifice *b*, and allows the extraction of the sand. The ball is prevented from rising too high by the perforated disk *c*.

Figs. 193 and 194.—A vertical section and external view of the borer, used to enlarge the hole. It is very solid, and consists of a hollow cylinder, whose inferior extremity is furnished on its circumference with fluted knives, of which there are several of different dimensions.

Fig. 195.—A view of the underneath part of the preceding.

Fig. 196.—Shows the mode of attachment of a knife to the ring, and also a front view of the knife The knives are firmly attached to the inner ring, and are surrounded by another ring of greater diameter. The whole is traversed by a pin.

ASH. See Woods, *varieties of.*



174. 175. 177. 176. 178 179. 183. 184. 185. 186. 80. 182. 181. 189. 190. 191. 192. 169. 170. 193. 195. 196. 194. 172. 173. 171. 187. 188.

ASPEN, See Woods, *varieties of.*
ASH, See Woods, *varieties of.*
ASHLAR, hewn stone used for the facings of walls. If the work be so smoothed as to take out the marks of the tools by which the stones were first cut, it is called *plane ashlar;* if figured, *tooled ashlar,* or *random tooled,* or chiselled, or bousted, or pointed: if the stones project from the joints, it is said to be *rusticated.*

ASHLERING, in carpentry, the fixing of short upright quarterings between the rafters and the floor.

ASH-PAN. In locomotive engines, an iron box attached to the fire-box to receive the ashes from the fire.

ASPHALTUM. Native bitumen. Its chief application is in the construction of roads and pavements, for roofing, and for protecting buildings from dampness. Its application to roads and pavements in this country has been unsuccessful, but it is still in use in Paris and other European cities.

Asphaltum varies considerably in purity, according to the quantity of different earthy substances mingled with it. When nearly pure its color is almost black, or dark brown, and it does not soil the fingers: when rubbed it gives off a pitchy odor. In combination with other substances it forms a mastic, which is applied in a liquid state to kitchen and stable floors, pavements, &c. The principal ingredient in "The Calcareous Asphaltum" which is found at Seyssel near the Jura Mountains, is a dark brown bituminous limestone. The stone is reduced to powder and mixed with a portion of mineral tar when intended to be applied as a cement, as in covering roofs, lining tanks, &c.; but when intended for flooring or pavements, sea grit is used in addition. This is melted and run into moulds about 18 inches square, by 6 inches deep, or formed into blocks weighing from 112 lbs. to 130 lbs. each. In this state it is sold for use, and is remelted on the spot where required, in cauldrons heated on small portable furnaces, with the addition of 1 lb. of mineral tar to 1 cwt. of mastic.

The only kind of tar to be used in this mixture, is that with which the limestone is impregnated. If the mastic is required to be very stiff, as for paving kitchen floors, a smaller proportion of tar is to be used, with a larger proportion of grit. To convert fine asphalte into coarse, 30 lbs. of fine clean grit are to be added to 112 lbs. of mastic, with from 1 lb. to 2½ lbs of tar.

In applying asphalte to the floors of cellars and basements to exclude dampness, an inverted brick arch laid in asphalte as a cement should be used. Asphalted bricks are also prepared by heating them, and placing them in rows upon a flat surface between gauges, allowing a layer of mastic a quarter of an inch thick to be laid over them: the brick are then separated with a knife before the mastic is quite set. The brick are also prepared by dipping the ends in boiling mastic.

The thickness of asphaltum used for pavements varies from half an inch to an inch and a quarter, the former for floors and the latter for carriage-ways: half an inch or five-eighths is sufficient for roofs and the coverings of arches, and about a quarter of an inch is sufficient for the ground line of brick-work to prevent damp from rising. An asphaltnm surface admits of easy repair. By placing hot mastic upon the place requiring it, the fresh material will readily adhere to the old work if free from dust or moisture. Asphaltum is used in oil painting; for which purpose it is first dissolved in oil of turpentine, by which it is fitted for glazing and shading.

ASSAYING. This term is applied in a confined sense to the analysis or separation of the precions metals from other metals; and to the determination of the quantity or value of gold and silver in bullion, coin, plate or trinkets, but more generally to the operation which decides the quantity of a certain kind of metal contained in an ore, or in an alloy, if it is performed by heat chiefly, in contradistinction to analysis, or the operation by moisture.

ATMOMETER. An instrument for determining the rate of evaporation from a humid surface.

ATMOSPHERE; that gaseous fluid which surrounds the earth, according to Dr. Prout, 100 cubic inches of which composes the atmosphere at the surface of the earth, when the barometer stands at 30 inches, and at a temperature of 60 Fahrenheit, weighs 31.0117 grains, being thus about 815 times lighter than water, and 11,065 times lighter than mercury. Since the air of the atmosphere is possessed of weight, it must be evident, that a cubic foot of air at the surface of the earth, has to support the weight of all the air directly above it, and that therefore the higher we ascend up in the atmosphere, the lighter will be the cubic foot of air; or in other words, the farther from the surface of the earth, the less will be the density of the air. At the height of three and a half miles, it was found that the atmospheric air was only half as dense as it was at the surface of the earth. From the nature of fluids, it follows, that the air of the atmosphere presses against any body which comes into contact with it; because fluids exert pressure in all directions, upwards, downwards, sidewise, and oblique. From the nature of fluids it also follows, that the pressure on any point is equal to the weight of all the particles of the fluid in a perpendicular line between the point in contact, and the surface of the fluid. The amount of pressure of a column of air, whose base is one square foot, and altitude the height of the atmosphere, has been found to be 2156 pounds avoirdupois, or very nearly 15 pounds of pressure on every square inch. It is common to state the pressure of the atmosphere as equal to 15 lbs. on the square inch. If any gaseous body or vapor, such as steam, exert a pressure equivalent to 15 lbs. on the square inch, then the force of that vapor is said to be equal to one atmosphere; if the vapor be equal to 30 pounds on every square inch, then it is equal to two atmospheres; and so on, consequently, the atmospheric pressure is capable of supporting about thirty inches of mercury, or a column of water 34 feet high. It is found that the pressure of the atmosphere is not constant even at the same place; at the equator, the pressure is nearly constant, but it is subject to greater change in the high latitudes. In this country the pressure of the atmosphere varies so much, as to support a column of mercury sometimes so low as 28 inches, and at other times so high as 31, the mean being 29·5. This would make the average pressure between 14 and 15 pounds on the square inch. In scientific books generally, the pressure is understood in round numbers to be 15 lbs., so that a pressure exerted equal to one, two, three, four, &c. atmospheres, means such a pressure as would support 30, 60, 90, 120, &c. inches of mercury in a perpendicular column, or 15, 30 45, 60, &c. pounds on every square inch.

ATMOSPHERIC ENGINE. See CALORIC ENGINE.

ATMOSPHERIC PRESSURE, applied to pile driving by Dr. Pott's system. Atmospheric pressure has been applied to the erection of several beacons in the vicinity of the mouth of the Thames. The first experiment was upon the Goodwin Sands on July 16, 1845, and an iron tube of 2 feet 6 inches diameter was driven into the sand to a depth of 22 feet in two or three hours. A gentleman, present at the experiment, which was made by the Trinity Brethren, said, that the facility with which this large iron tube was made to descend could be compared to nothing better than shutting up a telescope. The method of operation is this: the tubes are in convenient lengths, with spigot and faucet joints, and one of them being placed perpendicularly, an air-tight cap is fixed to the upper end. This cap communicates with a powerful air-pump, by means of which the air is exhausted from the tube, drawing up the sand or shingle with the water which ascends, and the tube immediately descends from the effects of outward atmospheric pressure. The contents of the tube are then removed by the pump, which readily draws away the sand or shingle with the water which rises during their action, and the exhaustion process is then continued. The upper end of the tube having become level with the surface, the operation is stopped, the cap removed, a fresh tube is affixed and secured, and the same course pursued, and thus continued, until, with the greatest facility, this great length of tube penetrated what must have been exceedingly hard sand.

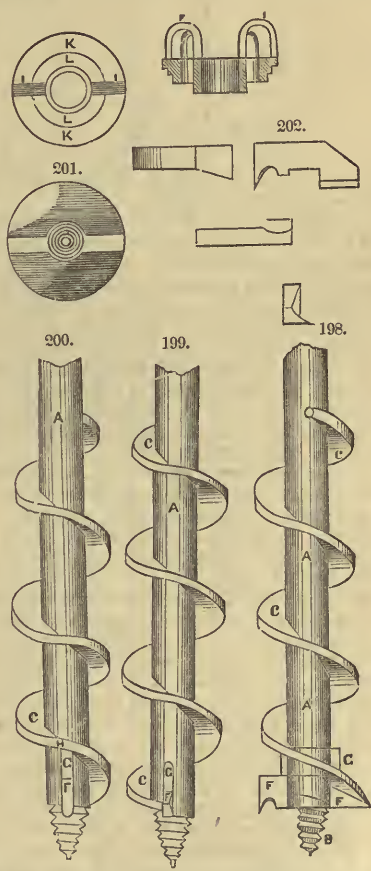
ATMOSPHERIC RAILWAY. See RAILROADS.

ATTRACTION. A tendency which certain bodies have to approach and adhere to each other. There are several kinds of attraction, as of gravitation, cohesion, capillary, chemical, electrical, &c.

ATWOOD'S MACHINE. See ACCELERATION.

AUGERS. See BORING TOOLS.

AUGER. Invented by Wm. Ash. An instrument to produce holes of various diameters, with the cutting and guiding parts detached, so as to change them at pleasure.



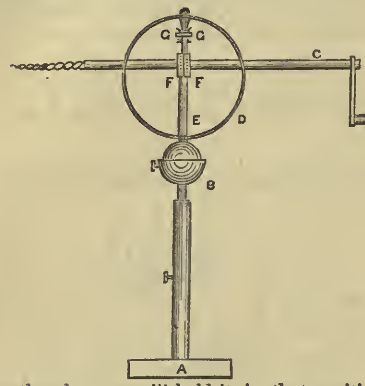
202. 201. 200. 199. 198.

Figs. 198, 199, 200, and 201, represent the auger in three different positions. Fig. 201 shows its end. A is the spindle; B the conical screw; C the worm fitted on the spindle. The upper end of the worm is made to bear against the stop D. F is the cutter fitted into a mortise in the spindle, fastened by the wedge-piece G. The cutter F, is shown above in four detached positions, Fig. 202. The lower end of the worm bears against the back of the cutter, and the wedge G rests also in a small notch cut in the face of the worm, as seen in Fig. 200. On taking out the wedge the cutter can be taken out, and also the worm, when another worm or cutter of a different size may be attached to the spindle. In this way the cutter can be taken out and sharpened at pleasure. Instead of the worm C, the guides, Figs. 203 and 204, are sometimes substituted. Fig. 203 is a vertical, and Fig. 204 a horizontal, section. This guide consists of a ring, K K, having a slightly conical screw-thread on the outside, from which extend two wings, I I, supporting a thimble, L. Through this thimble the spindle A passes, and the cutter being applied to bore the wood, the opening of the hole is only to be cut in the first place, then the ring of the guide is firmly screwed into that orifice; and in boring, the cutter will then be directed by the spindle sliding through the thimble. By the worm the chips are carried up out of the hole. By the guide the chips will rise through the opening K and the thimble L. The worm appears to be, by far, the best guide.

AUGERS, *machinery for making.* The object of the inventor, Mr. Palmer, is to manufacture the "single-twist" auger, usually made of a rod of metal, twisted round a cylinder into a helical curve. The auger which the inventor's machinery is intended to manufacture, is formed of a long rod of metal, (either of a triangular or other proper shape, in its cross-section.) The iron should be rolled in square bars or rods, of the size required, and be cut into pieces of sufficient length, to make the tool or instrument intended. A small piece of steel of proper size for the cutting-lip, and the conical screw, if it is to be added, is next welded upon one end of each one of the pieces, and the end is next turned or bent down at right angles to the remainder, upon an anvil, so as to fit into the cavity of the lower section of the dies, for forming the lip, or the lip and screw cone. About three-fourths of the length of the rod from the steel knob is next heated to the necessary temperature, to be rolled down by the next portion of the machinery. The next portion of the process of manufacturing the auger, consists in forming the cutting-lip, or the cutting-lip and conical screw-blank, upon its end. For this purpose, dies are employed to form the lip without the conic blank. The head of steel being heated, is placed between the dies, and the upper of them caused to descend, with the force necessary to swedge or compress the metal into the shape required. The knob thus formed, is next bent down to the angle re-

quired to be applied to the machine, by which the rod is twisted in the helical curve. The next operation is to give the requisite degree of uniformity to the size and spread of the twist, which is accomplished by hammering in the machine, consisting of a trip-hammer, arranged and operated over a die-anvil or bed-piece, grooved out, so as to receive the twisted helix when laid thereon. By turning the auger around, first in one direction and next in the opposite, successively, so as to cause it to pass back and forth between the hammer and bed-piece or anvil, the twist is spread out in a uniform manner. The lower part of the hammer should be curved to correspond with the circumference of the exterior of the twist of the auger. The twisted portion of the auger is again heated, and rolled between heavy iron plates, for the purpose of straightening the twist; during which operation care should be taken that the cutting lip of the auger does not come in contact with the plates. The auger is next to be finished by filing, and upon grinding and polishing wheels, or by other proper means, in such manner as may be desirable; and when a screw is to be connected with the cutting-lip, it may be cut upon the blank by any contrivance adapted to the purpose.

197.



Various machines are used to hold the auger in the required position whilst boring, of which the most common is that used by house carpenters for keeping the tool perpendicular to the face of the work. The foot of the frame rests upon the timber, and guides hold the auger at right angles to it: motion is conveyed through bevel geers and a crank. For ship carpenter's use, the following cut represents a frame invented by Richard Coffin, of Haverhill.

A is the foot. D is the frame. C is a rod and crank attached to the auger H. B is the cup and head. E is the spring. G G are two rods for the purpose of disconnecting the catches F F from the rod C.

If you wish to bore, pull the spring E by the handle to the left; shove down the left-hand rod G, to disconnect the left-hand catch from the rod C. The right hand catch holds the spring, and throws its power towards the auger H, and so on; the cup B allows its ball to roll in the auger and frame in any position, and the thumb-screw will hold it in that position; the other thumb-screw is to hold the slide which elevates or depresses the auger.

AUGERS, *double and single twist*, of Sandford, Newton and Smith of Meriden, Conn. Constructed with a uniformly decreasing length of twist, with a corresponding gradual tapering of the cavity of the auger, from the shank to the lower or cutting extremity. Any person skilled in the art of making augers can form the graduated double-twist with tongs and hammers, in the ordinary mode of twisting double-twist augers, by exercising due care and attention. A better method is to have the dies in what auger manufacturers call crimp-jaws, so constructed as to conform in size, graduated length of twist, and taper of the cavity, to the proposed auger. The auger having been first twisted by the common method, with the tongs and other tools, to about the shortness of a medium in the proposed twist, is, while hot, put into the crimps, which are then brought suddenly together by the usual process, the auger being at the same time turned partially round, backward and forward. The twist is thus made of a gradually increasing length, with a corresponding gradual enlarging cavity from the lower or cutting end to the other extremity of the twist.

To form single-twist augers with this improvement, that part of the rod which is to form the twist, should, before being twisted, be drawn with a graduated taper from the part which is to form the shank, to that which is to form the lower or cutting end. The auger may then be twisted in the usual way, by having the mould upon which it is formed or twisted, made to conform in size, graduated length of twist, and taper of cavity, to the proposed auger. The mould is a machine well known to all makers of single-twist augers.

The superiority of augers made with this improvement consists, in that the clogging of the chips or core in the twist, while in the process of boring, is effectually prevented; thereby materially diminishing the friction. And also, that the shortness of the twist at the lower end gives a better opportunity to finish the cutting-lips, so that they may bore more smoothly and evenly than when the auger is made in the ordinary way, with a slack or open twist.

What the inventors claim as their improvement and invention, is the making or constructing double or single twist augers, with a gradually increasing length of twist, and the consequent gradual enlargement of cavity from the lower or cutting end to the other extremity of the twist.

AUGER, *double-lipped, convex and concave*. Improvement in the form and construction of concave screw-augers, by N. C. Sandford, Meriden, Conn. This improvement consists as follows: Instead of having the plate, from which the auger is to be twisted, of concave shape throughout, as is usual in forming concave augers, the lower extremity of the plate is of convex shape, or of even thickness, though the former is preferred. In augers of five-eighths diameter it will be sufficient to have about one inch of the lower extremity of convex shape, or of even thickness, as aforesaid, varying in proportion as the diameter of the auger is increased or diminished.

The advantage of this mode of construction consists in, that the workman, when twisting the auger, which is done in the ordinary mode, is better enabled to give to the plate a short twist at the lower extremity, and finish the cutting-lips or edges in the best and most approved method for easy boring, than when the plate is formed in the usual way, of concave shape throughout.

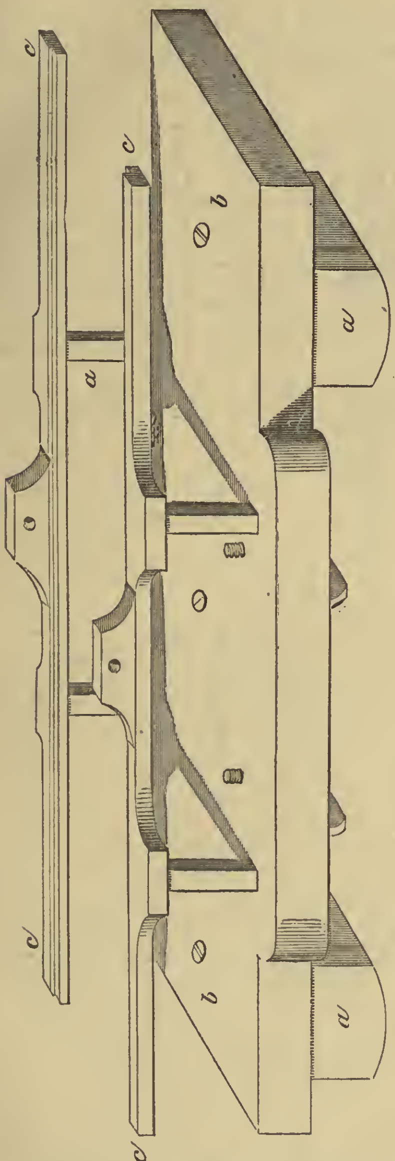
What Mr. Sandford claims as his invention, is the forming of the lower part of the plate of a convex shape, or of even thickness, when this is combined with the upper part of the plate formed of a concave

shape. The whole plate being formed for the purpose of making therefrom a double-lipped, convex, and concave auger.

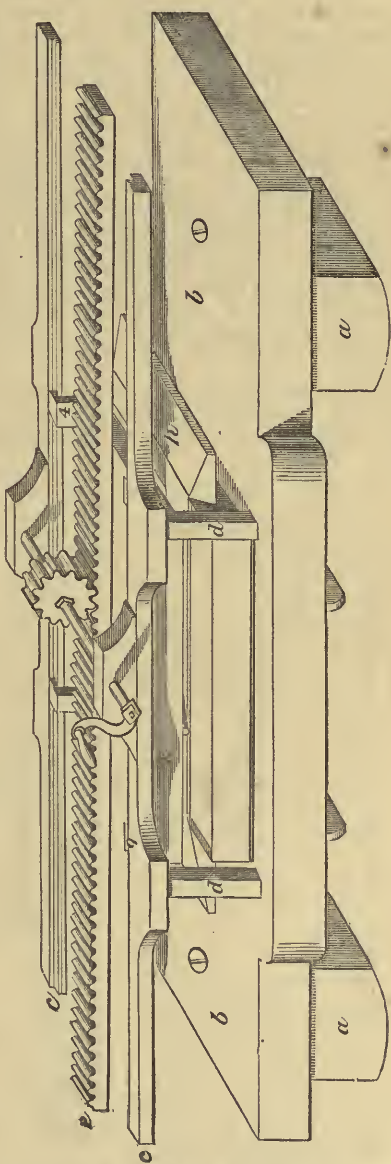
AUGER MACHINE. This new and useful improvement in the mode of equalizing and straightening the twist of double and single twist screw augers, invented by Sandford and Smith, of Meriden, Conn., may be described as follows:

Set firmly in the ground, or otherwise secure to the floor, two posts, marked *a*, Fig. 208, about six feet apart and fifteen inches in diameter, of sufficient length to elevate the machine to a convenient

208.



209.

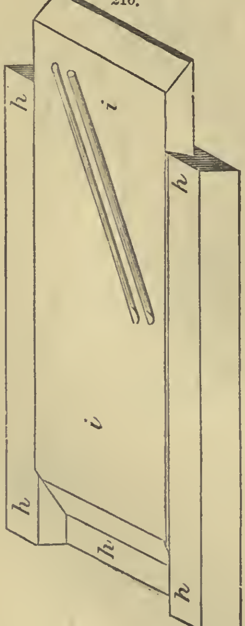


distance from the ground. Upon the upper surface of these posts is placed horizontally, and secured strongly, a piece of timber *b*, say of oak, about twenty inches wide on its upper surface, and four inches thick. This we term the bed of the machine. Two straight cast-iron bars *c*, about two inches thick and two inches wide, of the same length as the bed, and raised about twelve inches therefrom, and then placed about twelve inches apart, parallel to each other and to the bed. Each of these bars is secured to the bed by two vertical posts of iron, D. Fig. 208 shows the machine as thus far constructed. We then take a piece of cast-iron, say two feet long, fourteen inches wide, and one inch thick, with its edges raised about one inch, so as to form a dovetail on its upper surface. This we call the

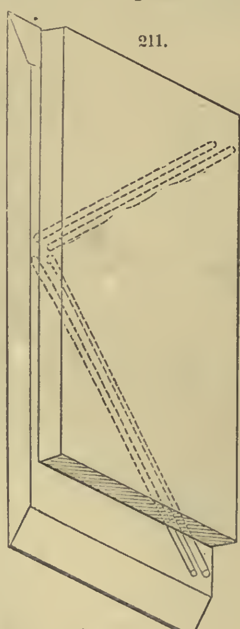
lower stock, and is represented by that portion of Fig. 210 marked h. This stock is placed in the centre of the bed, between the bars; screws passing through the bed and attached to the stock, serve to elevate or depress it at pleasure. Another screw, passing through the centre of the stock and through the bed, enables the operator to confine and hold the stock firmly on the first-named four screws.

Another piece of cast-iron, of similar dimensions, but with the dovetail on its under surface, is then placed under the bars, so that about one inch of each edge of the upper surface of its entire length shall bear upon the under surface of the bars. This we term the upper stock, and is held to the bars by four hooks, marked g, in Fig. 209, attached to the upper surface of the stock, and resting in the upper surface of the bars, so as to admit a sliding movement of this upper stock. This movement is effected by means of a rack e, and pinion; the rack, to be of sufficient strength, should be formed of a cast-iron bar, about two inches square, and of the same length as the bars, with cogs about two inches in length, and is attached lengthwise to the surface of the upper stock. The pinions and shaft should be of corresponding dimensions; and being turned by means of a crank or wrench, give an alternate backward or forward movement to the upper stock. Fig. 209 represents the machine with the upper stock k, and the lower stock h, in their respective places, and the rack e, and pinion attached. There are then inserted into these stocks, metallic plates, or dies, of about one inch thickness, which fit into and are securely held by the dovetails above mentioned. To each of these plates, or dies, are secured, by means of rivets or screws, two wales of cast-steel, running parallel to each other in an angular direction across the plates. Fig. 210 shows one of these plates i, partially inserted in the stock h. When the plates are separated from their respective stocks, the wales upon the plate are designed for the lower stock, and *vice versa;* so that when the plates are inserted in their respective stocks, the wales upon the upper plate run in an opposite direction from those upon the lower plate, forming an angle with each other. The size of the wales will depend upon the size of the auger to be formed; and the angle at which they cross the plate must be governed by the openness or closeness of the proposed twist, so that separate plates, adapted to each size of auger respectively, will be required.

If it is desired to form the auger so as to make the graduated twist, it may be effected by slightly curving and also tapering, as shown in Fig. 212, the wales; increasing or diminishing the curve and taper, in proportion to the degree of graduation contemplated.



210.



211.

212.

The plates are adjusted at the proper distance from each other, required by the size of the auger to be formed, by means of the screws.

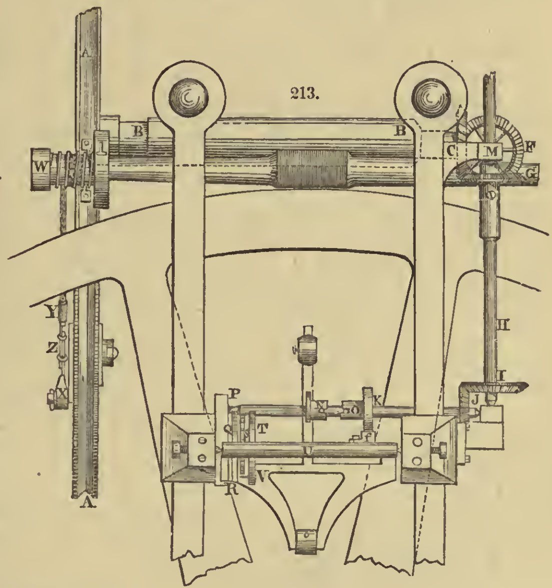
To work the machine the crank is turned backward, so as to move the upper plate directly over the opposite extremity of the wales upon the lower plate, as shown in Fig. 211. The machine is then ready for operation. The auger being twisted by hand in the usual way, (which can be done with great expedition, as particular nicety in this respect is rendered unnecessary by the use of the machine,) is placed while hot in the machine, with the part nearest the shank on the wales, which being adapted to the size of the auger to be operated upon, will fill the cavity of the twist. The upper plate is then moved forward by turning the crank, and rolls the twist part of the auger between the plates, these giving it an exact and uniform size; while, at the same time, the wales operate upon the cavities of the twist, opening or closing them as may be necessary, and by a single forward move-

ment of the machine, produces a perfectly even and regular twist. Thus forming a better article, and at less expense, than can be done by any method now in use.

Messrs. Sandford and Smith, claim the raising upon and securing to the surface of level metallic, or other plates composed of hard substance, wales running either in straight or curved lines, and operated substantially in the manner just specified, for the purpose of forming the twist of double and single twist screw augers.

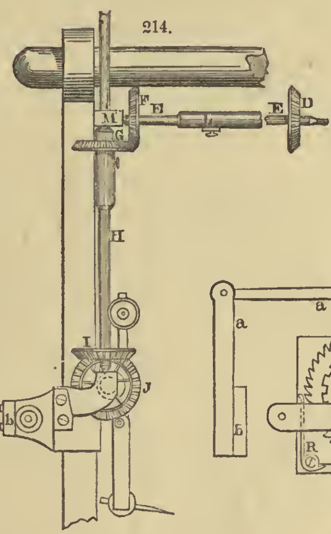
AUTOMATIC DIVIDING MACHINE, *arranged for use in the Coast Survey Office, by* Joseph Saxton, *assistant in the office of weights and measures, Washington, and constructed by William Würdeman, mechanician, coast-survey office.*—The dividing machine, which has been rendered automatic by Mr. Saxton, was imported for use in the coast-survey office, by the late F. R. Hassler, Esq., superintendent. The graduations made by means of it, by different persons, were unsatisfactory. Many causes were assignable for this, and it was considered by the present superintendent, Professor A. D. Bache, desirable that the most obvious of the causes of error should be got rid of, by rendering the machine automatic, before the minor causes of irregularity were sought for. This was done by Mr. Saxton, in the manner described in the following pages. The result has been very successful, not only in its first application, but in permitting the determination and removal of sources of error, previously concealed in the working of the machine. The drawings of the proposed additions upon a scale necessary for working, were made by Mr. Saxton, and the work was executed by Mr. William Würdeman and his assistant mechanicians in the coast-survey office. Accuracy, beauty of finish, ease of reading, economy of time, and labor in dividing, have all been gained by the improvements.

213.

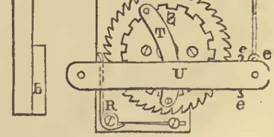


The machinery for rendering the dividing machine automatic, consists of a brass wheel A, about 20 inches in diameter, mounted on the axis B, Fig. 213. One of the arms of the wheel A has a slit extending from near the centre of the rim; in this slit is fixed the crank-pin so that it can be placed at any required distance from the centre. On the edge of the wheel is turned a groove, in which runs a cord for driving the wheel. On the other end of the axis is fixed the wheel C, which is geared into the wheel D, on the lower end of the vertical shaft E, Fig. 214. On the upper end of the same shaft, is another wheel F, geared into the wheel G, on the horizontal shaft H. On the end of the shaft H, is a wheel I, which gears into the wheel J, on the axis K. The wheels C D F G I and J are all bevel wheels, having the same number of teeth, (60) and work into each other at right angles.

214.



215.



The shaft E has on it a sliding-joint L, for altering its length; the shaft H is turned and ground of uniform thickness, so that it may slide accurately through the socket of the wheel G, and also through its bearing at M, in which it turns. The axis K has on it two eccentrics, N and O: N to raise the tracing point, and O to move it horizontally. One-half of the circumference of N is concentric with the axis on which it turns, so as to keep the point up while the crank-wheel moves half a revolution, and is moving the dividing plate. The other is eccentric to the axis about one-tenth of an inch, so as to let the point rest on the circle while it is making the division. The eccentric O has about $\frac{1}{8}$th of its circumference concentric to the axis; the rest is described from a point about $\frac{1}{8}$th of an inch from the centre. N and O must be fixed on the axis with regard to each other, so that N will raise the point before O begins to move it back, and both with regard to the crank-wheel A, so that the point

will be raised before the crank begins to move the dividing plate, and keep it up until it is done moving and O has moved the point back, and then let it down before O begins to let it return. The axis K has also on it, near the end, a small cog P, to shift the ratchet-wheel Q one tooth every revolution of K. The ratchet-wheel has 60 teeth, and is kept in its proper position by the detent spring R. In front of the wheel, and fastened to it by two screws, is a circular plate S, Figs. 213 and 215, with 20 notches in its edge, the deepest one for the longest line, or 5°; the next for 30′; and the shallowest for 15′; and the edge of the plate for the 5′ lines.

The segment T, Figs. 213 and 215, is fixed on the vertical part of the tracing-frame U, and has a pin in the end at V, of such a size that it can drop into the notches in S, as they are brought under it by the revolutions of the ratchet-wheel, and so regulate the length of the division lines. The time of raising the ratchet must be when the stop-pin is raised out of the notch, by the motion of the traces backwards. To give motion to the screw, a stout fusee-chain is used, one-eighth of an inch broad, and one-fourteenth of an inch thick, which answers well; one end is attached to the ratchet-barrel W, round which it is wound five or six turns; the other end is attached to the crank-pin X. Near the lower end of the chain, at Y, is a small tube, containing a strong spiral spring, arranged like the common spring weighing-machine, but having a motion of only about $\frac{1}{8}$th of an inch; the spring must be so strong as not to give by the force required to turn the screw, but only to give a little when the ratchet comes up to the stop, and the crank is just passing the lower centre. Between the spring and the crank-pin is an arrangement for lengthening or shortening the chain, when it is arranged for making a larger or smaller division; for this purpose, two pieces of brass wire, about six inches long, having a screw cut on them their whole length, and each filed away one-half, and two small milled nuts, tapped with the same thread, are run on each; the two wires are laid together, and the nuts screwed up until they embrace both wires, as shown at Z, Fig. 213.

The crank-pin is fixed on a slide, projecting beyond the nut which fastens it, so that it may be extended, if necessary, beyond the circumference of the wheel, or by reversing, it may be brought quite to the centre. When the divisions are to have the long end towards the centre, a jointed lever, as shown at *a*, Fig. 215, is used. It is screwed fast to the cross-bar *b*, Figs. 214 and 215, directly over the eccentric O, and connected to the vertical framo U at *c*, and the stop-pin V is shifted to the other end of T, and the abutting piece *f* on U, is to be removed, when the eccentric O will act against the lever *a*, at *d*, and move the point in an opposite direction. The tracing-frame is made to follow the eccentric, by a weight and cord passing over a pulley and hooked to the vertical part of the tracing frame at *e e*, Fig. 215.

When the adjustment is made for dividing with the long end of the division lines, towards the circumference of the circle, all the wheels connecting the axis K with the axis B should be marked with a dot on the tooth and space in which it works, and a line should be drawn on the shafts E and H, and a corresponding mark on the sockets through which they pass, so that they may always be fastened in the same position. The axis K should have two short pins fastened on it, and notches in the ends of the sockets N and O, to fix them in their proper position when the lines are towards the circumference or centre, as the case may require. The slit in the crank-wheel A, in which the crank-pin is fastened, should also be graduated, showing the distance of the pin from the centre, for each degree, minute, and second that may be required in dividing.

By marking the position of each part of the machine in this way, much time and trouble will be saved in making the necessary changes for different kinds of dividing, whether it be in the number, or the direction in which the long lines are to be extended. The tracing point should be adjusted so as not to be raised more than about the thirtieth of an inch, or it will be liable, in descending, to make a small dot at the commencement of each line, which would injure the appearance. In the drawing, the eccentric N is represented as acting on the tail of the tracing-frame, but it is better to make it act on a steel pin in the side of the tail.

By this arrangement of the crank for turning the dividing-screw, the stops of the ratchet are brought in contact when the crank is passing its centres, and the motion of the screw is so slow, that it is not possible for the stops to strike so hard as to do any injury, and the dividing may be done with great rapidity.

AWLS. See Boring Tools.

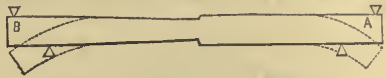
AXLE. A shaft supporting a wheel; the wheel may run on the axle, or be fastened to it, and the axle turn on bearings. For size and form of mill axles or shafts, see Gearing.

ON THE FORM OF RAILWAY AXLES. A very extensive course of experiments has been gone through by Mr. Thorneycroft, approximating as closely as possible to the forces on axles when in use, with a view to ascertain the best form to be given to axles, to enable them to resist fracture or deflection. The railway axle is viewed as having certain relations to a girder in principle. Girders generally have their two ends resting on two points of support, and the load is either located at fixed distances from the props, or dispersed over the whole surface; of the axle the wheels may be considered the props, and the journals the loaded parts. It is found that the inclined surface of the wheel tire given by coneing, ranges from 1 in 12 to 1 in 20, and, as a matter of course, the direct tendency of the wheels under a load is to descend that incline, so that every vertical blow which the wheels may receive is compounded of two forces, viz: the one to crush the wheels in the direction of their vertical plane, and the other to move the lower parts of the wheels together; it will be seen that these two forces have a direct tendency to bend the axle somewhere between the wheels.

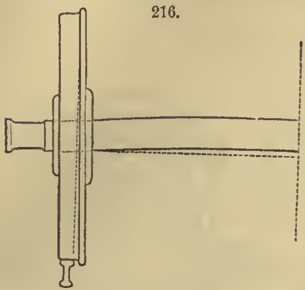
An axle reduced in the middle to $1\frac{3}{4}$ inch diameter, was placed upon two props 4 feet 9 inches apart, and loaded in the middle, the utmost of its deflection without a permanent set, was .232 inches, the load carried 7 tons. An axle reduced to 4 inches in the middle, and then placed upon the props 4 feet 9 inches apart, its utmost deflection without a permanent set was .281 inches, the load carried 9 tons. Another axle, but parallel $4\frac{5}{16}$ inches diameter, was placed upon the props 4 feet 9 inches apart, its utmost deflection without a permanent set, was .343 inches, the load carried 14 tons. Hence by reducing an axle of $4\frac{5}{16}$ inches diameter in the middle to $3\frac{3}{4}$ inches, its limit of elasticity is reduced from .343

inches to .232 inches, and the load, to produce that elasticity, from 14 to 7 tons. Fig.216, shows the position of the wheels to the rails when the bending of the axle has exceeded its elastic limit.

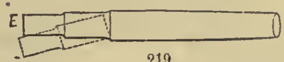
217.



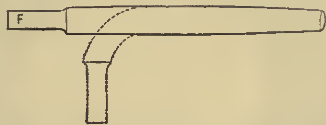
216.



218.

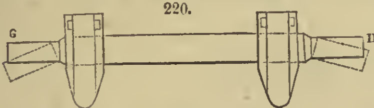


219.



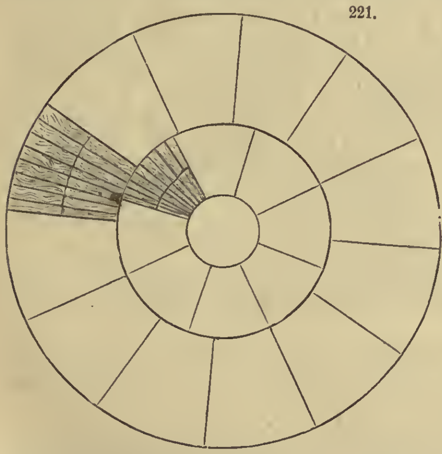
To ascertain what influence the reduction of an axle in the middle would have on its strength to resist sudden impact, compared to an unreduced one, an axle was made as represented by fig.217, which shows the end A, parallel to the centre, 4½ inches diameter, and the end B is drawn down from the back of the wheel towards the centre, where it is 4 inches diameter. The end A was then subjected to impact—the relative position of the prop and ram was the back of the wheel and the neck of the journal, this end received 46 blows of the ram, and bent to an angle of 18°. The end B was then subjected to impact—the prop and the ram in the same relative position, when it bent back to an angle of 22° with only 16 blows of the ram (as shown by the dotted lines in fig.217. The object of the third experiment was to ascertain what influence a shoulder behind the wheel would have on the strength of the axle at that part, compared to one without a shoulder. Figs.218,219, were one axle cut in two, and the end E was turned from the neck of the journal, leaving a shoulder ⅛th inch deep, as a stop to the wheel; the end F was turned from the neck of the journal to the same diameter, but no shoulder left. The end E was subjected to hydraulic pressure, the load being in a direct line with the shoulder, when it broke in two with a load of 60 tons. The end F was subjected in the same way to hydraulic pressure, when it bent into the form shown by the dotted lines, with 84 tons. To ascertain what influence the position of the wheel, in relation to the neck of the journal, would have on the strength of the journal under impact, fig.220, a piece of an axle with a journal taken down at each end was used; the end G was keyed into a cast-iron frame, the face of the frame in a line with the neck of the journal, the journal was then subjected to the impact of a ram, falling 10 feet. when it broke off at the seventh blow. The end H was keyed into the cast-iron frame in the same way, but with the neck of the journal projecting 1½ inch from the face of the frame, the journal was then subjected to the impact of the same ram falling 10 feet, when it broke at the 24th blow.

220.



From these experiments it is obvious that neither shafts nor railway axles ought to be reduced in the middle, but rather, if there is to be a departure from the parallel form, they should be made thickest in the middle, and thus effectually prevent any vibration or bending whatever.

221.



Railway axles are mostly made solid, those drawn under the hammer being better and safer than those that are rolled. Fig.221, represents the section of a fagoted axle, as constructed by the Brunswick Iron works, England; * the segments show the forms of the pile composing the axle. Fig.222, is a section of a hollow axle as constructed at the same works. Fig.223, a plan of the same axle with a portion taken off showing the cavity.

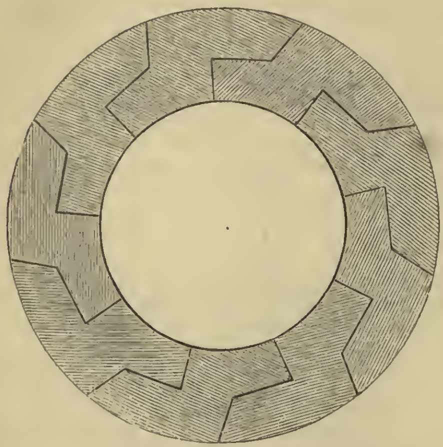
The selection of the tubular form of axle originated from the knowledge that, with a considerably less weight of material in the form of the tube, a much greater strength can be obtained to resist torsion, deflection by pressure or weight, or concussion from blows. The use of hollow axles was tried some years ago, but was not continued, the main objection being that there appeared a great difficulty of insuring, by the particular mode of manufacture adopted at that time, a sufficient uniformity of thickness of the sides of the tube through out, and also of the soundness of material. Since then a mode of manufacturing hollow railway axles has been introduced, which, it is believed, secures the utmost strength with the least possible amount of material, uniformity of structure of the iron, perfect equality of thickness of material, and soundness of manufacture.

The plan adopted is as follows: A number of segmental bars of the best quality of iron are rolled to

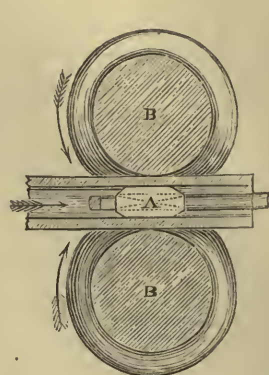
* Geo. W. Billings agent, 66 Broadway, New York.

a section, so as to form, when put together ready for welding, a complete cylinder about 1½ times the diameter of the axle when finished, the bars fitting correctly together, so as to have no interstices, and overlapping in such a manner as to insure a perfect and sound weld when completed.

222.



224.



223.

This cylinder of loose segmental bars is temporarily held together by a screw-clip, and each end being put into the furnace until a welding heat is produced, the bars are then partially welded together, and the clip removed. The whole cylinder is then placed in the furnace and brought to a proper welding heat: it is then passed through a series of rollers, B B, fig.224, which have each a mandril of an egg form A, in the centre of the circular opening, which is attached and supported on the end of a fixed bar, the bar being firmly secured at the opposite end to resist the end pressure of strain during the process of rolling. The mandrils are made of cast-iron, chilled, fitting on like a socket on the end of the bar to a shoulder, and they are secured by a screw-nut, so that they are easily removed when required.

The motion of the rolls is so arranged by a reversing clutch on the shaft, that as soon as the axle cylinder has been drawn clear through, the motion is reversed, and the axle which has been drawn on the mandril-rod, is again drawn back through the same openings in the rolls; it is immediately passed through the next smaller groove of the roll, with a decreased size of mandril, and again reversed back through the same groove in a similar manner, and so on through a series of grooves in quick succession, each decreasing in size, and consequently increasing the compression and strength of the iron of which the axle is formed; and by the last groove it is passed through, it is reduced to the proper diameter. At each time it is changed from one groove to another, the axle cylinder is turned by the workmen a quarter round, so as to equalize the pressure on every part of the surface, to insure uniformity of the compression of the iron, and thoroughly complete a sound welding throughout every part of the axle. The axle, after being welded and drawn down in the rolls to the proper size, is taken at once to a hammer, where it is planished between semicircular swages over its entire surface. A small jet of water plays upon it during this process, which enables the workmen to detect at once, by the inequality of color, any unsoundness in the welding. From the hammer it is taken to the circular saws, where it is cut accurately to the length required, and ready to have the bearing formed upon it. The ends are reheated, and gradually drawn down by a hammer to the proper dimensions and form of the journals, a mandril being inserted in the end of the tube during the process of hammering.

The weight of two axles of the solid description finished is, say 5 cwt., and if replaced with hollow axles of equal strength, the weight may be reduced 1½ cwt. Two different kinds of bearings are used, the parallel bearing with the rounded shoulder, and also the double conical bearing. In either description of bearing the hollow axle is good, although it is believed that the conical bearing for either the solid or hollow axle has less tendency to injure the texture of the iron during the formation of the journal than the parallel shouldered axle.

The experiments on transverse strength by a heavy weight falling on the centre of the axle, and giving the blow on opposite sides alternately, show that the hollow axle is nearly double the strength in that respect of the corresponding solid axle, the amount of bending being only 5 inches instead of 9¾ inches; and the number of blows required to break the hollow axle being 29, whilst the solid axle broke at the fifth blow, shows the hollow axle to be greatly stronger in resistance to fracture. The experiments on strength of journals show that, instead of the journals breaking off square and short at the shoulder, as in the solid axles, the hollow axle journal stands a considerably greater number of blows, and then only splits up longitudinally, instead of breaking off transversely, being a very important advantage in point of safety in working.

BACKING. In masonry, the filling in behind the face of the wall.

BACK-LINKS. The links in a parallel motion which connect the air-pump rod to the beam.

BACKWATER. Water in the race of a mill, and rising above the bottom of the wheel.

BAKING. See BREAD.

BALANCE, as applied to machinery, refers to parts in equipoise, as balance *Docks*, *Gates*, *Valves*, which, See.

BALANCE. A well known modification of the first order of levers, commonly called the beam and scales. See SCALES.

BALLASTING. A term applied to the covering of roads generally, and to the filling-in material, above, below, and between the several stone blocks and sleepers upon railways, &c.; it is laid for the purpose of keeping the road dry, as in the event of water lying upon it, the rails invariably sink, as it causes them to rest unequally. Ballasting is composed of gravel, broken stone, or the like, and is laid about two feet thick on railways, and it is generally from 6 to 12 inches thick on roads.

BALLISTIC PENDULUM. See GUNPOWDER.

BALKS. Long pieces of timber.

BALUSTERS. Small columns or rods capped by a rail.

BAR. A piece of timber or metal placed horizontally, and running across from one part of any framework to another.

BAR, (in navigation.) An accumulation of sand or shingle at the commencement or mouths of rivers, harbors, &c., being formed by the action of the tides.

BARBERY-WOOD. See WOODS, *varieties of.*

BAROMETER. An instrument used for observing the pressure and elasticity, or variations in density of the atmosphere. It is commonly employed for the purpose of determining approaching variations in the weather; and more scientifically for measuring altitudes. There are various modifications of the barometer, as the Diagonal, Horizontal, Marine, Pendant, Reduced, and Wheel Barometer; in all of which the principle of construction is the same—the only difference being in its application.

The essential part of a barometer is a well-formed glass tube, closed at one end, perfectly clear and free from flaws, 33 or 34 inches long, of equal bore, filled with pure mercury, and inverted, the open end being inserted in a cup partly filled with the same metal, so that the mercury in the tube may be supported by atmospheric pressure.

The vacant space between the top of the mercury and the top of the tube is called the Torricellian Vacuum, in honor of the inventor of the instrument.

On pouring mercury into the barometer-tube and inverting it, the air thus confined between the mercury and the inner surface of the tube, will escape into the Torricellian vacuum. In order to get rid of this air, as well as moisture, the tube is first gently warmed, so as to dry it thoroughly. A quantity of pure mercury is then poured in, so as to occupy two or three inches of the sealed end of the tube, which is held over the fire until the mercury boils, taking care to turn the tube round upon its axis, so that the heat may be equally applied. After boiling for a minute or two, the open end is closed by a cork to prevent the introduction of moist air, and the tube is then allowed to cool, in order that the cooled mercury which is next to be poured in may not crack the tube. When a second portion of mercury, about equal to the first, has been poured in, the part of the tube containing this new portion is held over the fire until it boils. It is again removed from the fire, and corked up as before. A third portion of mercury is then introduced, and the heat again applied to that part of the tube containing the last addition of metal; and in this way the tube is at length filled, with the exception of a small portion from which the mercury has been expelled by the heat. This is filled up with mercury, and the finger is now placed over the opened end so as carefully to exclude any air; the tube is then reversed into a cup of pure mercury; as the column sinks, it expels the last portion of mercury which had not been boiled; and as there is neither air nor aqueous vapour above the mercurial column, its length exactly measures the atmospheric pressure. A film of air is always retained on the outside of the tube, and also at its under edges, which film creeps by small portions at a time into the interior, and rises up in innumerable bubbles into the vacuum, the film being constantly renewed by the descent of more air between the outside of the tube and the mercury in the cup, and thus the outer air slowly insinuates itself into the barometer. In this way the most carefully constructed barometers have become deteriorated in the course of years.

This irregular and uncertain deterioration of barometers was remedied by Professor Daniell, by uniting a ring of platinum with the open end of the barometer-tube, so as to bring it into contact with the mercury, thus effectually preventing the ingress of air into the tube.

The same philosopher also invented a new mode of filling barometer-tubes, by pouring the mercury into the tube while both are under the exhausted receiver of a good air-pump. The mercury is poured through a long slender funnel extending to the bottom of the tube, and dipping into a small portion of mercury previously introduced, and boiled. By this means all agitation is confined to the tube of the funnel, and the tube left perfectly free of air. The mercury was afterwards boiled *in vacuo*.

The excellence of the barometer chiefly depends on the absence of all matter except mercury from the tube, and its value may be tested by three indications:—*First*, by the brightness of the mercurial column, and the absence of any flaw, speck or dulness of surface; *secondly*, by the *barometric light*, as it is called, or flashes of electric light in the Torricellian vacuum, produced by the friction of the mercury against the glass, when the column is made to oscillate through an inch or two in the dark; *thirdly*, by a peculiar clicking sound, produced when the mercury is made to strike the top of the tube. If air be present in the tube, it will form a cushion at the top, and prevent, or greatly modify, this click.

The sectional area of the tube is of no consequence, as the atmosphere presses with the same intensity upon the surface of the mercury in the cup, the column suspended in the tube will be of the same height, whatever its internal diameter.

The height of the mercurial column must be measured from the surface of the mercury in the cistern. When the atmospheric pressure increases, and the mercury in the tube rises, a portion of the metal is drawn out of the cistern into the tube, and the level of the mercury in the cistern is depressed so, on the contrary, when the atmospheric pressure diminishes, a quantity of mercury is forced out of the tube into the cistern, and the level of the metal in the latter rises.

In some instruments the scale, accurately divided into inches and parts of inches, is made movable, and terminates in an ivory point, which is brought down to the surface of the mercury. When this point and its reflection appear to be in contact, the height indicated by the scale is correct. In other forms of the barometer, the mercury in the cistern is always maintained at the same level, for which purpose the cistern is formed partly of leather, so that, by means of a screw at the bottom, the surface of the mercury may always be adjusted to the neutral point before taking an observation. The divisions of the scale usually begin at the 27th inch, and are continued to the 31st. But in instruments intended to measure the height of mountains, or for accompanying balloons, the scale begins at the 12th or 15th inch. Each inch is divided into ten parts, and these are subdivided into hundredths by means of a small sliding scale, called a *vernier* or *nonius*.

The words "Change," "Fair," and "Rain" engraved on the plate of the barometer, are calculated to mislead; in winter a fine bright day will succeed a stormy night, the mercury ranging as low as 29 inches, or opposite to 'Rain.' It is not so much the *absolute* height as the actual rising and falling of the mercury, which determines the kind of weather likely to follow.

The barometer ought to be fixed in a truly vertical position, and if possible with a northern aspect, in order that it be subject to as few changes of temperature as possible. It is usual, for the sake of comparison, to reduce the observations to 32°, for which purpose tables for correction for temperature are given in scientific works devoted to the subject of the barometer. The height of the cistern of the barometer above the level of the sea, and, if possible, the difference of the height of the mercury with some standard, should be ascertained, in order that the observations made with it should be comparative with others made in different parts of the country. Before taking an observation, the instrument should be gently tapped, to prevent any adhesion of the mercury to the tube; the gauge should be adjusted to the surface-line of the cistern, and the index of the vernier brought level with the top of the mercury.

Various contrivances have been made for increasing the length of the scale, or for making it more convenient for use. The most popular form is the common wheel-barometer, as it is called. In this instrument, the tube, instead of terminating at the bottom in a cistern, is recurved so as to form an inverted siphon. As a rise of the mercury in the longer or closed limb is equivalent to a fall in the shorter limb, and *vice versa*, a float is placed on the surface of the mercury in the shorter limb, and is connected with a string passing over a pulley, and very nearly balanced by another weight on the other side of the pulley. An index hand attached to the pulley moves over the surface of a dial-plate, graduated so as to indicate the oscillations of the mercurial column. With an increase of atmospheric pressure the mercury in the longer tube rises, and that in the short tube is depressed, together with the float, and this gives a small motion of revolution to the pulley, and also to the attached index hand. A fall in the longer column causes the mercury with its float in the short limb to rise, and consequently moves the index hand in the contrary direction.

The *measurement of heights* was the first useful purpose to which the barometer was proposed to be applied.

Although the atmosphere may extend to the height of 45 miles, yet its *lower half* is so compressed as to occupy only $3\frac{1}{2}$ miles, so greatly do the upper portions expand when relieved from pressure

Hence at the height of	$3\frac{1}{2}$ miles,	7 miles,	$10\frac{1}{2}$ miles,	14 miles,	&c.
the elasticity of the atmosphere is	$\frac{1}{2}$,	$\frac{1}{4}$th,	$\frac{1}{8}$th,	$\frac{1}{16}$th,	&c.

Halley was induced, by certain mathematical considerations, to fix upon the number 62,170 as a constant multiplier, and the rule for the measurement of heights may be stated as follows:—Observe the height of the barometer at the earth's surface, and then at the top of the mountain, or other elevated station; take the logarithms of these numbers, and subtract the smaller from the greater; multiply the difference by 62,170, and the result is the height in English feet. This process gives a very near approximation, especially in temperate climates.

But the progress of science soon rendered it evident that a correction for temperature was necessary in barometrical measurements, and a formula has been contrived to meet most of the difficulties of the question. The following rule will be found of easy application:—Multiply the difference of the logarithms of the two heights by the barometer, by 63,946; the result is the elevation in English feet. Then, in order to correct for temperature, take the mean of the temperature at the two elevations; if that be 89·68° Fahr., no correction is necessary; if above that quantity, add $\frac{1}{450}$th to the whole height found for each degree above 69·68°; if below, subtract the same quantity. For example: Humboldt found that at the level of the sea, near the foot of Chimborazo, the barometer stood at exactly 30 inches, while at the summit of the mountain it was only 14·85. The logarithm of 30 is 1·4771213, and the logarithm of 14·85 is 1·1717237; then subtracting

$$\begin{array}{r} 1{\cdot}4771213 \\ 1{\cdot}1717237 \\ \hline 0{\cdot}3053976 \end{array}$$

Multiply this by 63,946, which produces 19,539 for the elevation in feet. If the mean temperature of the two stations were 69·68°, no correction is necessary for temperature. This is a tolerably close ap

proximation: the most careful calculation has given 19,332 for the real height, and this was probably estimated for a lower temperature.

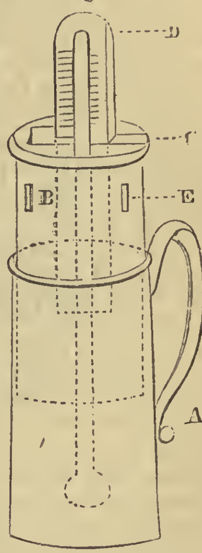
A method has been given by Leslie for measuring heights without the use of logarithms. His rule is as follows:—Note the exact barometric pressure at the base and the summit of the elevation, and then make the following proportion:—As the sum of the two pressures is to their difference, so is the constant number 52,000 feet to the answer required in feet. Suppose for example the two pressures were 29·48 and 26·36; then

As 29·48 + 26·36 : 29·48 — 26·36 : : 52,000 feet : 2,905·4 feet, the answer required.

This rule has been found applicable to the mean temperature of England for all heights under 5,000 feet.

Another method of obtaining approximate differences of altitude, is by a comparison of the *temperatures* of boiling water (which vary with the pressure of the atmosphere). The apparatus is exceedingly simple, and the instrument not so liable to injury as the mercurial barometer, being much more portable, and easily replaced. A. Common tin pot 9 inches high, by 2 in diameter. B. A sliding tube of tin, moved up and down in the pot; the head of the tube is closed, but has a slit in it. C. to admit of a thermometer passing through a collar of cork, which shuts up the slit when the thermometer is placed.

Fig. 1



D. Thermometer with so much of the scale as may be desirable.

E. Holes for the escape of steam.

The boiling point for the level of the sea should be correctly marked by a number of careful observations, and the difference, if any, must be noted as an index error.

These thermometers are very useful in ascertaining heights where strict accuracy is not required, and they have the advantage over mercurial barometers in being portable. In moderate elevations, the difference of *one degree* in the temperature at which water boils, indicates a change of level of *about* 500 *feet*, corresponding to a difference of 0·6 of an inch in a mercurial barometer. See ANEROID.

BAR-WOOD. See WOODS, *varieties of.*

BARREL, (of a drum-wheel.) The cylindrical body or axle round which the rope is rolled.

BARREL, (of a pump.) The cylinder, or hollow part of the pump, in which the piston works.

BARROW. See WHEEL-BARROW.

BARYTES, found in tolerable abundance in Wales, and some parts of England, and also in the State of Connecticut. The salts of barytes employed in the arts and manufactures, are confined to the carbonate and sulphate. The use to which the native carbonate has been applied is the preparation of the various salts of barytes, which are made by saturating the respective acids with the powdered native carbonate.

An artificial carbonate is used in Birmingham in the manufacture of plate and flint glass, as a cheap substitute for part of the alkali. It is also used in the manufacture of porcelain, jasper, &c.

Sulphate of Barytes is employed as a pigment and also for the purpose of adulteration. It is known as "permanent white," and is made by precipitating the sulphate from a soluble salt of barytes, by means of sulphuric acid, which when washed and dried forms a beautiful white powder, that is not acted upon by sulphuretted hydrogen gas. It is to this that it owes its superiority over white lead as a water-colour. Oils destroy its whiteness, and render it nearly transparent; so that it is only useful as a water-colour.

The sulphate of barytes used in adulterating white lead is made by levigating the whitest varieties of the native sulphate, and afterwards bleaching it by boiling with dilute sulphuric or muriatic acid, for the purpose of dissolving out any iron which it may contain. When washed and dried it forms a dense white powder. Some of the native sulphate is sufficiently pure as not to require the bleaching process. That which is white and soft, possessing little or no crystalline structure, is preferred by the manufacturer, being easily reduced to powder. The presence of barytes in white lead can easily be detected by dissolving out all the carbonate of lead, by dilute acetic acid. The sulphate of barytes being unacted upon, can then be washed, and the quantity ascertained by weighing.

BASE LINES, (in surveying.) The main lines of a survey, upon which the correctness of the whole depends; it is therefore necessary to proceed with the utmost care in the laying out of the several base lines of a survey.

BASE LINE. (In perspective.) The intersection of the plane of the picture with the ground plane.

BASKET. A kind of vessel made of osier, wicker, rushes, straw, whalebone, &c. The weaving of baskets is entirely hand work, but simple machines are used in the splitting of the materials. For strong, heavy baskets, strips of ash are considered the most serviceable.

BASE. A rest or support; particularly applied to the bottom of columns, pedestals and edifices.

BASES. In chemistry, a term applied to all the metals, alkalis, earths, and other bodies, which unite with acids, or with gases. Thus in sulphate of copper, the copper is said to be the base of the salt, from the supposition that the non-acid principle is that which gives diversity or distinctness of character to compounds. The term is now retained from its convenience, rather than the truth of the above opinion.

BAT. The name given to a half or other portion of a brick.

BATTENS. Strips of board or plank, from $1\frac{1}{2}$ to 6 inches wide, nailed over the joints of other boards; often ornamented with a bead or corniced to give architectural effect on the cheaper class of houses. Batten doors are such as are made of two thicknesses of boards nailed together; generally the boards are nailed crossways of each other, but often diagonally.

BATTER. The face of a retaining, or other wall, when built in a leaning position, the top part falling back within the line of base; walls of this description are sometimes termed *tallus walls*. The usual batter is from 1 to 3 inches horizontal for each foot in vertical height. See MASONRY.

BATTERY. Two or more pieces of artillery, united for the purpose of dispersing troops, or destroying that which covers and protects them. It is also used to signify the equipment of a certain number of pieces of ordnance.

BAY. In architecture, the space between the beams or arches. A part of a window between the mullions is often called a bay or day.

BAY-TREE. See WOODS, *varieties of.*

BEAM, in building, usually a horizontal piece of timber or metal. For the proper form of simple beams to resist the required strains, see STRENGTH OF MATERIALS—for the relation of the parts of a trussed beam, see BRIDGE. The term working or walking beam is applied to the balance lever, transferring the power from the piston of common draught engines to the crank. See ENGINE.

BEARING. That part of a shaft or spindle which is in contact with the supports. See GEERING.

BEARING. The distance that a beam or rafter is suspended in the clear between supports.

BED. A term used in masonry to describe the direction in which the natural strata in stones lie; it is also applied to the top and bottom surface of stones when worked for building.

BED-MOULDINGS. A collective term for all the mouldings beneath the corona or principal projecting member of a cornice.

BEECH. See WOODS, *varieties of.*

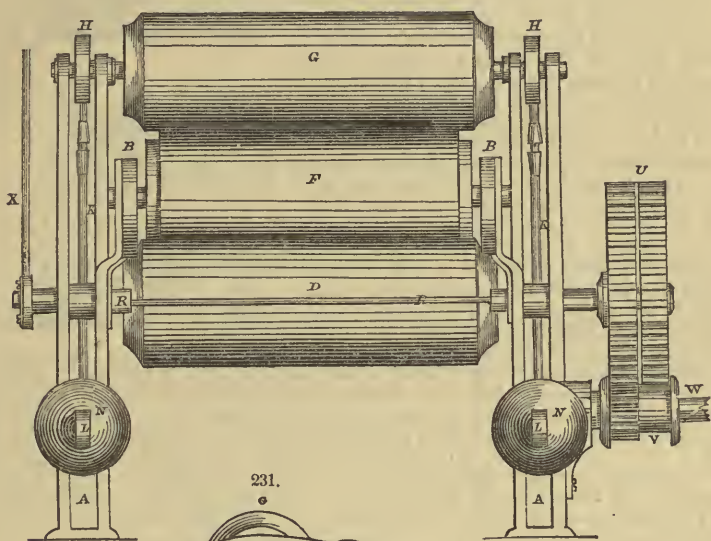
BEEF-WOOD. See WOODS, *varieties of.*

BEETLE. A heavy wooden mallet or rammer.

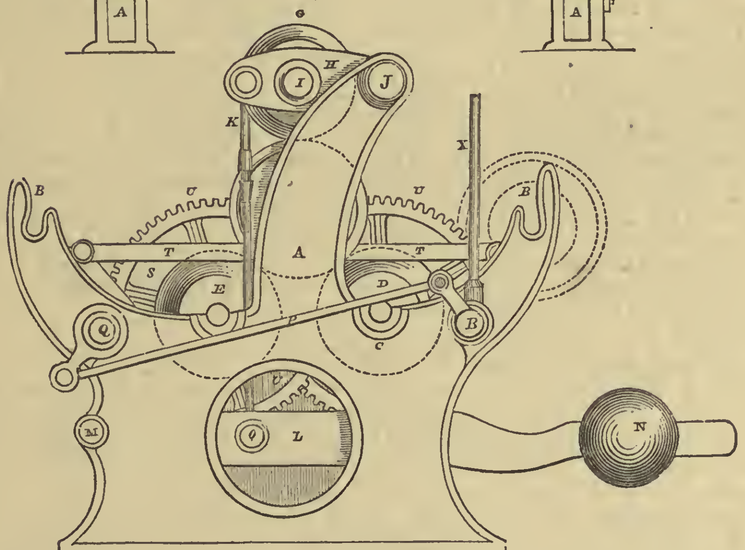
BEETLING MACHINE. A machine used in bleacheries to give to cotton fabrics a soft, glossy appearance. The usual form consists of a cylinder, on which, as the cloth is rolled, it is beaten by stampers similar in their construction to those used in gold crushing; see METALLURGY. An invention has been made to give the same finish by rolls as in a calender, of which the following is the description. The accompanying engravings represent at Fig. 230 a front elevation, and at Fig. 231 an end elevation of the above-mentioned machine, with the same letters of reference applying to similar parts. A A are cast-iron standard frames, having side-claw projecting bearings B B, Fig. 231, with two central horn-shaped ones A^1, carrying the pressure-lever links; C C are bush-bearings for the journals of the beetling rollers D and E, which rotate horizontally with each other in opposite directions; F F is the roller upon which the cotton fabrics, about to undergo the beetling process, are wound; G G is the pressure-roller, mounted in the lever-link motion-head H H, upon the central horn-standard *j*, in a manner subsequently explained; I is the shaft upon which the pressure-roller revolves; K K two connecting-rods on each side of the machine, attached in vertical positions at the top to the links H H, and at their lower ends to the weighted levers L L; M is the centre stud, upon which the levers L L radiate; N N are two spherical-shaped balls or weights, for giving pressure to the roller G, through the medium of the levers L L, assisted by their own gravity; O is the bearing on which the connecting-rods K K move; P is an intermediate crank motion-rod, coupling the two way link-shafts V R, and giving motion horizontally to the longitudinal rest-bars T T, through the quarter-way links S S, in gear with the same; U U are two spur-wheels, mounted upon the beetling roller-shafts D and E, in gear with a pinion V, on the driving-shaft; W X is a long hand-lever, the object of which is to raise the different rollers from their beds by it in the manner hereafter explained. Having thus far described the various arrangements and parts of which this invention consists, it is necessary to explain its mode of working, and the numerous advantages that may result from its application to the various purposes for which it is intended. Steam, or other motive power, is in the usual manner first applied to the driving-shaft W, which is mounted in a bracket bearing against the standard-framing, as represented in the engraving; whilst the other end is similarly mounted against a wall or other convenient place, and when driven by the action of steam, it causes the pinion V, on the end, which takes into the spur-wheels U U, to propel the same, and thereby give the required motion to the machine or apparatus during the process of beetling. It must be observed, that the cotton fabrics about to be mangled or beetled, are first wound upon the roller F; to accomplish which, the roller has to be removed or taken out of its place, which is performed in the manner hereafter explained. Having completed the operation of winding the cotton on the rollers, it is then passed between the beetling-rollers D and E, which are furnished with peripheries, such as are seen in the two smaller engravings annexed; these are embossed, or checkered in different patterns corresponding to the rollers employed. The fabrics are then taken from the rollers and replaced by others, during the working of the machine, and the operations effected. The pressure to which the fabrics are exposed by the constant rotation of the rollers between which they pass, is produced and carried into effect as follows:—The roller G G, with its moveable link-bearings on each side, centred on the horn-shaped standards, are caused, through the medium of the side connecting-rods K K, to receive the entire weight of the levers L L, in addition to the weights H H on the ends, and consequently offer a sustaining pressure to the fabrics during the process of beetling. On the other hand, when it becomes necessary to supply the apparatus with plain cotton fabrics, and remove those already beetled, the levers L L, which are represented as having holes at one end for the employment of any suitable or convenient tackle, are to be by such means raised, the action of which will have the effect of raising also the head-links and pressure-roller, and thus, by removing the weight, enable the roller beneath to be lifted out of its seat, and placed in one of the end claw-bearings B B, as represented by the dotted lines. The mode of effecting this part of the operations will

be readily comprehended by reference to the engraving, Fig. 231, where T T shows a bar of iron horizontally placed on each side, beneath the journals of the roller F, forming a rail or table upon which they are to be moved. When a downward motion of the lever handle is given by the operator, it causes the coupling-rod P, through the medium links P R, in connection with others on the same shaft, in gear with the rest-bar T T, to move upwards horizontally, similar to the action of a parallel rule, and raise the rollers F or B out of, or into their respective places, by enabling the rollers to be rolled along them, when disengaged from their bearings or seats, and carefully lowered into their places, in readiness for the next operation. From these observations it will be seen that, first, the levers L L are to be raised in the manner which will cause the roller G G to be also raised, through the medium of

230.



231.

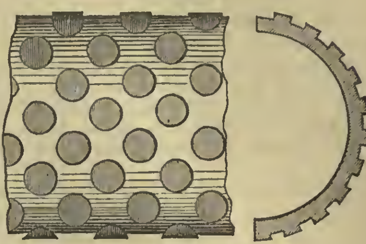


the connecting-rods K K, when the pressure will be removed from the lower rollers, and which will enable them to be raised to the required height, so as to transfer them from one seat or bearing to another, and thus allow the fabrics to be changed by removing those already having undergone the process, and supplying the other roller with plain ones. The patentee, although he describes and sets forth the employment of the side-levers, yet does not confine himself exclusively, as other and equally effectual means may be applied with the same advantages, such as steam pressure, liquids, or otherwise; and in many cases the weight of the rollers themselves might be found sufficient to give the required pressure without the intervention of additional pressure.

The next object to which the patentee directs attention, is to the improved mode of constructing roller-mangles, which consists of very nearly the same arrangement of rollers, the only apparent difference being, the introduction of a flexible lever or spring, firmly fixed to the standards upon which

the pressure-roller is mounted, being brought to act upon the same to any degree of force, by the application of a hand-wheel and screw-spindle, supported in bearings, suitably arranged. To the end of the screw-spindle two fixed studs are attached, between which the lower end of the flexible lever or spring is introduced, so that when the spindle is screwed to or from the centre of such standard, carrying the roller, the pressure is applied by reason of the standard moving from a centre with the roller under an elastic pressure thus given by the forward or backward application of the screw hand-wheel spindle. The patentee states that cast-iron rollers may be employed for dry articles, but for damp ones, bell-metal would be found better adapted. One of the advantages derived from this system of mangling is the small space the machine occupies, together with the accommodation which it offers by being placed within a piece of furniture having drawers for the purpose of disposing of the various articles when so mangled, and thus forming a very useful piece of furniture, and which may, if necessary, be rendered highly ornamental in place of the present incommodious machine now in use. The same principle also extends to a portable description of mangle, which the patentee states may be temporarily set up on a table or dresser, and made to answer all the purposes for which it is intended, motion being given to it by hand-levers in the usual manner, but employing, as a means of giving pressure, a lever, as in the first-mentioned instance; but with this difference, that the connecting-rod K, in the beetling apparatus, has in this instance a rack and pinion as a means of adjusting it, so as to obtain the requisite pressure. The patentee, after describing the peculiar forms given to the several rollers comprising a series of different patterns, and the best means of constructing them and forming the corrugations or indentations upon them, would wish it to be distinctly understood, that he claims as new and of his invention:—First, the employment of rollers having indented, grooved, checkered, or undulated surfaces or peripheries, for producing by pressure corresponding marks or impressions therewith upon cotton or other fabrics. Secondly, for the general arrangement of parts constituting the action and construction of the said improved machinery. Thirdly, for the employment of water or other fluids within the aforesaid rollers, to act independently of other pressure apparatus, such as the long levers in Figs. 230 and 231, of the annexed engravings; also for the application of steam to such purposes, causing, in the usual manner by its expansion within a cylinder, a pressure to be exerted upon the rollers, and at the same time that such application should be available for the purposes of taking off and removing the pressure when required, the same means employed for the one shall be found effectual in performing the other. Fourthly, and lastly, for the use of the numerous patterns as applied to cylinders employed in the process of beetling, or to other like machines or apparatus, either for mangling, or otherwise, as hereinbefore fully detailed. See CALENDERS.

232.



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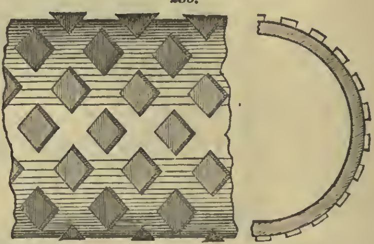


BELLS. The bell of the Montreal Cathedral is the largest in America. Its proportions are as follows:—diameter at mouth, 8 ft. 7 in., at shoulder, 4 ft. 8 in. Height to shoulder, 5 ft. 11 in. The thickest part, or sound bow, is 8 inches. Weight $13\frac{1}{2}$ tons. See CASTINGS AND FOUNDINGS.

BELL-CRANK. A bent lever or arc, used chiefly in the hanging of bells, to allow the wire to accommodate itself to the alteration of motion requisite in turning corners.

BELL-METAL. See METALS AND ALLOYS.

BELT, in building, a string-course and blocking-course; a course of stones projecting from a wall, either moulded, plain, fluted or enriched.

BELTING. A belt is a band or strap, passing from one pulley over another, serving to convey motion between shafts. Belting is usually employed at speeds varying from 300 to 5,000 feet per minute. The size of the belt will depend on the power to be transmitted. A certain degree of tension, varying with the width of belt and size of pulley, and, to a considerable degree, with the tractive nature of the surface of the pulley, as well as the amount of resistance, is required to prevent slipping. This force or tightness may be equal throughout its parts, while the machinery is at rest, but when in active operation, it becomes far otherwise. It is evident that the only force tending to induce motion in the driven pulley is the difference in tension between the two parts of the belt. A portion of the belt extends from opposite sides of the pulley, in nearly parallel directions, and each portion tends by its pull to turn the pulley in opposite directions. If the driven shaft is performing any work, there must necessarily be a difference in the tension of the parts, and this, however rapidly the belt may be moving, so that every portion is alternately exposed to a greater and a lesser strain. It is also equally plain, that other things being equal, this difference in strain is directly proportioned to the amount of work or power which is transmitted. This strain is then determined by dividing the power to be transmitted by the velocity; thus, if a belt moving at a velocity of 1500 feet per minute, be required to transmit 5 horse power; that is, $33000 \times 5 = 165000$ lbs. ft.; then $\frac{165000}{1500} = 110$ lbs., the strain on the belt to convey the power. In addition to this strain, it must be remarked, that the belt is stretched on the pulleys, so that it does not slip while conveying the power. The strain given above may be considered approxi-

mately as the difference of tension between the two sides. Morin gives the following Table to deter mine the strain on each side of the belt.

Portion of the circumference embraced by the belt.	VALUE OF K.			
	New belts on wooden drums.	Ordinary belts		Wet belts on iron pulleys.
		On wooden drums.	On iron pulleys.	
0.20	1.87	1.80	1.42	1.61
0.30	2.57	2.43	1.69	2.05
0.40	3.51	3.26	2.02	2.60
0.50	4.81	4.38	2.41	3.30
0.60	6.59	5.88	2.87	4.19
0.70	9.00	7.90	3.43	5.32
0.80	12.34	10.62	4.09	6.75
0.90	16.90	14.27	4.87	8.57
1.00	23.14	19.16	5.81	10.89

Application of the table.—Find in the table the value of K according to the given circumstances; from this number subtract unit or one, and divide the strain on the belt to convey the power by this remainder, and the quotient will be the minimum tension or that on the *slack* side. Add to this quotient 10 per cent. for friction due to shafting, or other causes. The tension on the leading or *tight* belt will be the above product added to the strain, as given by the power required to be conveyed.

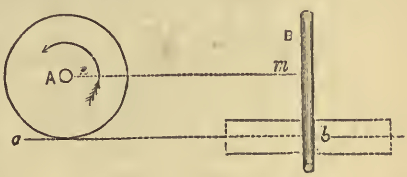
Applying this to the example above of a strain on the belt of 110 lbs. with the ordinary belt embracing $\frac{1}{2}$ or 0.50 of the circumference, the value of K in the table is 2.41; subtract 1, = 1.41; 110 divided by 1.41 = 78 lbs.;

78 + 10 per cent. or 78 + 7.8 = 85.8, the tension on the slack belt.

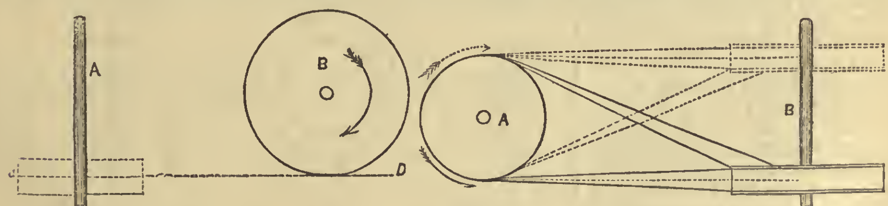
85.8 + 110 = 195.8, the tension on the tight belt.

Good belting of an ordinary thickness of $\frac{3}{16}$ of an inch should sustain a strain of 50 lbs. per inch of width without risk, and without serious wear for a considerable time. Therefore, in the example above, the belt moving at a velocity of 1500 feet per minute, required to transmit a power of five horses should be $\frac{195.8}{50}$, or very nearly 4 inches in width.

When the belt is shifted, whilst in motion, to a new position on a drum or pulley, or from fast to loose pulley, or *vice versa*, the lateral pressure must be applied on the *advancing* side of the belt, on the side on which the belt is approaching the pulley, and not on the side on which it is running off. It is only necessary that a belt, to maintain its position, should have its advancing side in the plane of rotation of that section of the pulley on which it is required to remain, without regard to the retiring side. On this principle, motion may be conveyed by belts to shafts oblique to each other. Let A and B (fig. 261) be two shafts at right angles to each other, A vertical, B horizontal, so that the line run perpendicular to the direction of one axis is also perpendicular to the other, and let it be required to connect them by pulleys and a belt, that their direction of motion may be as shown by the arrows, their velocities will be as 3 of A to 2 of B. On A describe the circumference of the pulley proposed on that shaft; to this circumference draw a tangent $a\,b$ parallel to $m\,n$, this line will be the projection of the edge of the belt as it leaves A, and the centre of



the belt as it approaches B; consequently, lay off the pulley b on each side of this line, and of a diameter proportional to the velocity required. To fix the position of the pulley on A, let fig. 262 be an



other view taken at right angles to fig. 261, and let the axis B have the direction of motion indicated by the arrow, then the circle of the pulley being described, and a tangent $a'\,b'$ drawn to it perpendicular to the axis B as before determined, the position of the pulley on the shaft A is established.

The position of the two pulleys are thus fixed in such a way, that the belt is always delivered by the pulley it is receding from, into the plane of rotation of the pulley towards which it is approaching. If

the motion be reversed, the belt will run off; thus (fig. 263), if the motion of the shaft A is reversed, the pulley B must be placed in the position shown by the dotted lines.

It is not an essential condition that the shafts should be at right angles to each other to have motion transferred by a belt. They may be placed at any angle to each other, provided the shafts lie in parallel planes, so that the perpendicular drawn to one axis is perpendicular to the other. If otherwise, recourse must be had to guide-pulleys, which should be considerably convex on their face.

It is to be observed that the faces of pulleys are generally made more or less convex, as the tendency of a belt in motion is to mount the highest part of the pulley; by a slight rounding of the face, therefore, the belt preserves its proper position.

BENCH, or BERM. A ledge on the face of a cutting.

BENCH MARKS, (in surveying.) Fixed points left on the line of survey, for reference at any future time, consisting of cuts in trees, pegs driven in the ground, and the like.

BENDING OF TIMBER. See Woods, *varieties of.*

BENZOLE. An oil prepared from coal tar, extremely volatile: if a stream of air be passed through a reservoir of Benzole, it will imbibe enough of the vapor to become an inflammable and luminous gas. On this principle many arrangements have been patented for illumination of buildings by benzole, but as yet the manufacture of benzole is too expensive.

BETON. See Mortar.

BEVEL, any angle except one of 90 degrees. The term bevel is also applied to an instrument for drawing angles, in general use among workmen. In construction, it somewhat resembles the common square, with this difference, that the blade is movable about a centre in the stock, so that it can be set at various angles.

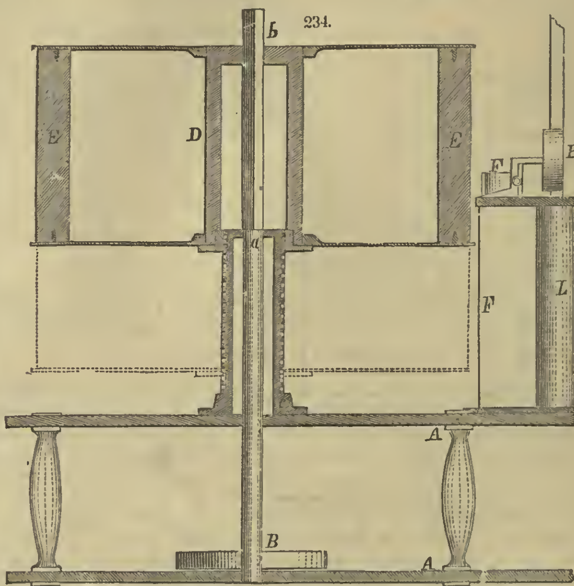
BEVEL WHEEL. See Geering.

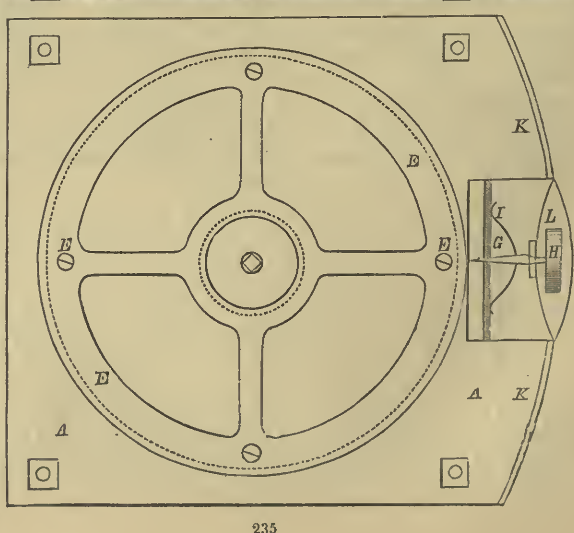
BINNACLE, a box near the helm, containing the compass.

BIRAM'S TELL-TALE. *Description.*—Fig. 234 is a side elevation in section, and Fig. 235, a plan of the apparatus, (on a scale a little less than half size.)

A A is the frame, supposed to contain the works of a portable timepiece, of which B is the fusee; C is a hollow screw, fixed upon the frame A, through which the axle of the fusee is prolonged, being supported by, and turning in a circular opening at *a*, above which the axle is square, the diagonal of the square being equal to the diameter at *a*; D is a hollow tube, having a female screw fitted into the bottom, to turn easily upon the male-screw C; the top of the tube D has a square opening to fit easily upon the square end of the axle of the fusee; which axle should project about half an inch beyond the tube D, when in the position shown in the figure, to receive the key or handle used in winding up the timepiece; E is the barrel or cylinder, round which the registering paper is placed, which should be made to fit upon the tube D, sufficiently tight to retain its position wherever placed, but capable of being easily turned round upon the tube, or slightly elevated or depressed, for the purpose of adjusting it to the index F, to show the time of the day, and also to adjust the registering lines with the pricker G. F, the index showing the time, is a fine wire, placed vertically as near as possible to the cylinder, the ends being secured in a frame attached to A. The top of the frame also carries the pricker G, placed exactly over the wire F, which is acted upon, and makes an

234.





235

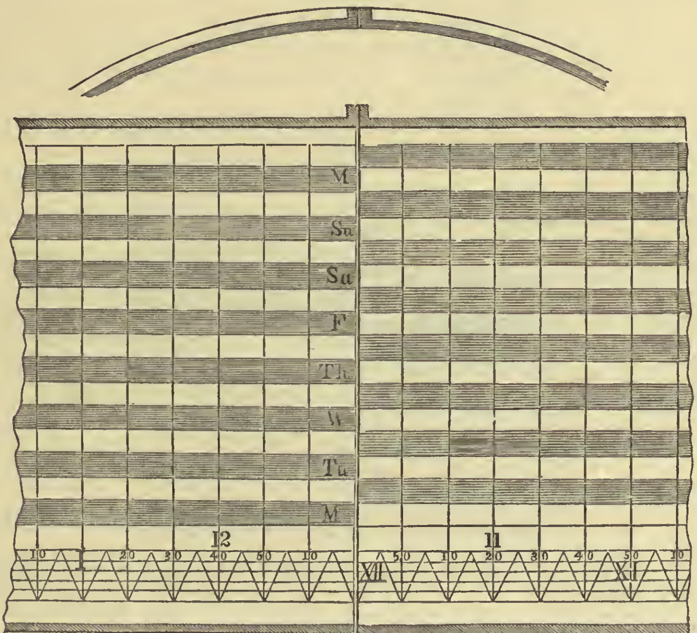
impression upon the registering paper, when a finger is pressed upon the stud H; I shows a slight spring, intended to return the pricker and stud to their position when the finger is removed; L is a piece of glass in front of the timepiece, the horizontal section of which is that of a double convex lens, but the sides vertically are parallel with each other; this magnifies the parallel and diagonal lines upon the paper which show the minutes, *horizontally* only, showing the time more distinctly to the fraction of a minute; K K are two pieces of plane glass, on each side of L, for the purpose of throwing more light upon the barrel.

Fig. 236 shows a portion of the registering paper, of the full size, with the shaded lines upon it indicating the days of the week; this paper is of exactly the circumference of the cylinder, and is put upon a strip of leather, gutta percha, or other flexible material, also of the length and width of the barrel, to each end of which is riveted a strip of brass, having a projection on each side to catch into a notch in the projecting flanges of the barrel. When the registering paper is changed, the barrel may be taken off from the tube D, and the leather and paper from the cylinder; and then a new paper put on, the ends of the paper being turned underneath the leather, and retained by any adhesive application, such as that made use of in postage stamps.

The registering paper is divided vertically by twelve equidistant parallel lines, representing the hours, and again subdivided between each of the above lines by other finer lines into ten minutes. On the lower edge of the paper are five parallel lines crossed by two diagonal lines between each of the above subdivision or ten-minute lines, by which each subdivision is again divided into minutes, the time of the day being shown by the point when the index wire F intersects these small parallel and diagonal lines. The shaded lines representing the days of the week are not drawn parallel with the edge of the paper, but in such a manner that when the paper is fixed round the barrel the shaded lines at one end of the paper fit opposite the intervals at the other end, these shaded lines and intervals being each exactly equal in width to the pitch of the screw C.

Now, suppose the timepiece newly wound up, and a new registering paper placed upon the barrel at midnight on Sunday: (of course this untimely hour is not necessary, as the operation may be done at any time of the day.) The barrel will then have been removed from the position shown by the dotted lines in Fig. 234, to the shaded part above in the same figure, and the pricker G would then be oppo-

236.



site the commencement of the underside of the line M, (Fig. 236,) and every part of the underside of that line would by 12 at noon have passed under the point of the pricker; when the barrel having made one revolution would also have descended one thread of the screw, and during the next revolution the upper side of the line M, representing the afternoon hours of Monday, would have passed under the pricker, and so on through the week; the lower side of the line representing each day passing under the pricker during the forenoon, and the upper side on the afternoon of such day. It is therefore obvious, that any impression made upon the paper by the pricker, would show the day and the exact time of day when such impression was made, and when the paper was removed from the barrel the punctures remaining upon it would be an enduring testimony, to be consulted and checked at leisure, of the operations recorded upon it during the week.

The uses to which this tell-tale might be applied are various. If as a watchman's clock, it may be used by several people who are required to be at a certain spot at certain or uncertain intervals. When a person presses upon the stud, he should be required to make a memorandum of the time by the clock

these memoranda he would give up to the inspector at the end of the week, who would compare whether the punctures upon the paper corresponded with the return; and if not, the writer would of course be detected making a false statement. In an establishment where there are a number of individuals, and it is desirable to ascertain the time of their attendance, they might be required to write their names, and the time of their arriving, in a book, at the same time pressing the tell-tale; when, although several might arrive and sign so near together that the punctures upon the paper might run one into another, yet the time between the first and last would be distinct, and if the names were written in succession, it would be evident that they had been written during the time between the first and last puncture. Again: any individual leaving an establishment during the day, might be required to write his name in the same way, with the time of his leaving and returning, at each time pressing upon the tell-tale, which would be a great check against a person absenting himself improperly, or being absent too long. It might also readily be applied to registering the performance of a steam-engine, or other machinery, by so connecting it with the machinery that the pricker should puncture the paper after a certain number of strokes of the engine, or otherwise.

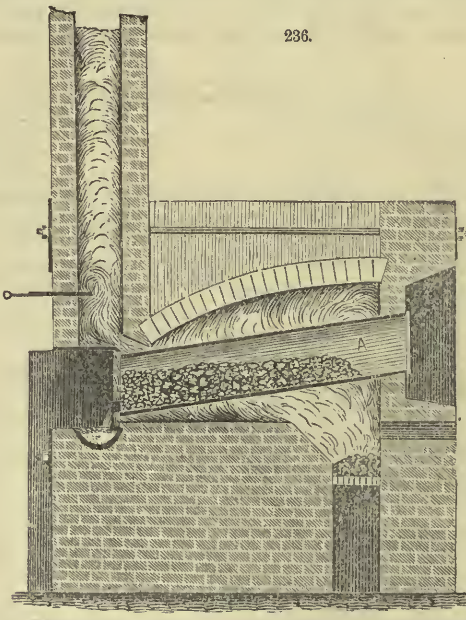
The tell-tale, as in the engravings, is shown attached to a portable timepiece, regulated by a balance escapement; but it is applicable also to a common eight-day clock, with slight modifications.

BIRCH. See Woods, *varieties of.*

BISMUTH, is a rare metal, but its distinguished qualities are that it is very fusible, and causes other metals to become so. It melts when pure at 480°; it may be distilled in a close vessel, and then crystallizes in laminae. It is very brittle, like antimony, and of a brilliant lustre; its color is white, tending to flesh-color. Its specific gravity is 9·83, which may be increased to 9·88 by hammering. It expands in the act of cooling, which renders it peculiarly suitable for castings.

The operation of smelting bismuth is extremely simple; the metal having but a weak affinity for other substances is obtained by simply heating its ore in a modern liquation furnace, Fig. 236. A, is a

236.



cast-iron retort, at the highest part of which the crude ore is charged. B shows a cast-iron bowl into which the metal flows. About half a cwt. of broken ore is charged in each retort, of which there are four in a furnace side by side. This quantity nearly half fills a retort, so that the upper part of it is empty. The lower end of it is closed with a clay plate, or slab, provided with an aperture for the discharge of the melted metal. The pipes, when properly heated, soon cause the metal to flow into the dish B, which contains some charcoal-dust. By applying a brisk fire and some stirring to the ore, all the metal contained in it is obtained within half an hour. The residuum of the ore is now scraped out of the retort into a trough with water, and the pipes are filled afresh. About a ton of ore is smelted in a day of eight hours. The metal is remelted, cast into iron moulds in the form of ingots, and is now ready for the market. See Metals and Alloys.

BITS AND BRACES. See Boring Tools.

BITTERNUT-WOOD. See Woods, *varieties of.*

BLACK BOTANY-BAY WOOD. See Woods, *varieties of.*

BLAST-FURNACES. See Iron.

BLASTING. The operation of detaching and separating blocks of stone or earth from their natural or quarry beds, which was usually performed in former times by the following process:—Long wooden wedges were driven, in a very dry state, into holes prepared for them, and previously well heated; a quantity of cold water was then poured over the wedges, which, upon becoming thoroughly saturated, swelled and caused a fracture of the rocks. The same effects are now generally produced by the ex-

ploding force of gunpowder, which was first used for that purpose about the year 1620. A hole is first driven into the stone by a jumper, or chisel, which is held in a proper direction by one man while another strikes it with a hammer, the former turning his instrument at every blow, to form a round hole; sunk to various depths, from 1 to 3 feet, according to circumstances. If water appears in the hole, some stiff clay is crammed in, by which it is absorbed, and the fissures through which it entered filled up. When the hole is of some considerable size, and of great depth, a long runner succeeds the jumper, 6 or 8 feet long, and chisel-pointed at both ends, which is lifted up and dropped into the hole, and being heavy, perforates the rock. For deep holes a second longer runner succeeds the first. When sufficiently deep, the hole is charged with powder, and a small taper rod or needle of copper is inserted, so as to reach the bottom of the hole; the remaining space is *tamped* or filled up with broken bricks and clay; the needle is now withdrawn, and the vent thus formed filled with fine powder, which is ignited by a match.

Since the introduction of the safety-fuse, the copper needle is dispensed with, as well as the tamping bar, by the use of which premature explosions were frequent. The safety-fuse is made by machinery. String is coiled so as to form a cylinder, which receives the powder specially manufactured for the purpose, and by a continuous operation the fuse is formed in coils of any length. In practice, the charge of powder is placed in the hole and the required length of fuse carried down to it; the hole is then filled slowly with dry sand and tamped with a pointed stick. The fuse is left projecting sufficiently above the hole to be readily lighted, and of length enough to enable the workmen to withdraw before the explosion.

In blasting operations of magnitude, the steam drill is effectively employed. See Drill.

When it is desired to move large masses of rock, as in excavating ledges, it is usual to open a seam, as it is termed; this is effected by drilling a very deep hole, and charging it with a quantity of powder only sufficient to separate the mass to be moved. The seam thus made is then partly filled by pouring in powder, and tamping it with dry sand. The charge is then ignited by means of a safety-fuse in the usual manner.

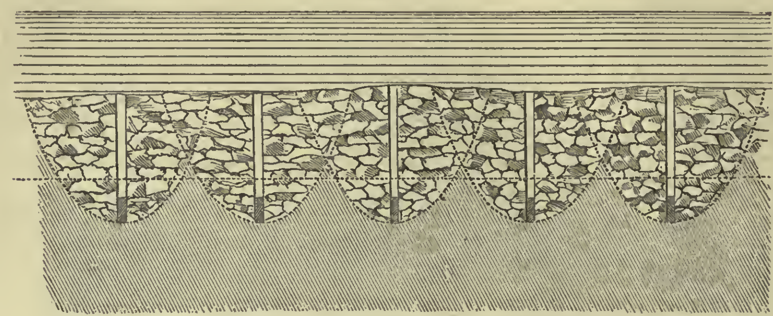
The galvanic battery has been successfully applied to Blasting, both on land and under water. It is well known that a piece of platinum or iron wire when made to connect two copper wires leading from two poles of the battery, instantly becomes red-hot, and capable of igniting gunpowder, or even of igniting a spirit lamp. For dry blasting two insulated wires connected at the bottom with a piece of platinum wire are inserted into the charge, and after the usual tamping, the powder is exploded by establishing a galvanic current through the wire by means of a battery. For submarine blasting, more precautions are necessary to insure the insulation of the wires and the keeping of the powder dry. The charge of powder is contained in a canister, in the top of which is fixed a cork coated with sealing-wax, through which descend, water-tight, two vertical copper wires, reaching into the middle of the charge. These are separate during their whole course except at the bottom, where they are connected by a fine platinum wire; and at the top they rise a little way above the cork, and are curled round into two distinct loops. After the charge is introduced, the top is cemented on the canister with putty; two copper wires, wound with cotton and coated with varnish, are then connected with the wires in the canister, one to each loop, and of sufficient length to reach from the point of explosion to the battery, which is at a sufficient distance to insure safety, either in a boat or upon land. A double chain of communication then exists, properly insulated, from the boat to the charge of powder, which has been fixed in the required position by a diving bell or other means. It is then only necessary to bring one wire into connection with each pole of the galvanic battery, which by the passage of the galvanic fluid heats the platinum, and ignites the powder in the canister. A battery of six cells is sufficiently powerful when using a length of 100 yards of wire.

The galvanic battery was employed in the operations at Round-Down Cliff, near Dover, Eng., in 1843, when a mass of chalk estimated at 291,666 cubic yards was displaced by a single explosion of 18,000 lbs. of gunpowder, ignited by the galvanic current. The wires used were each 1,000 feet in length, and it was ascertained by experiment that the electric fluid will fire powder at a distance of 2,300 feet of wire.

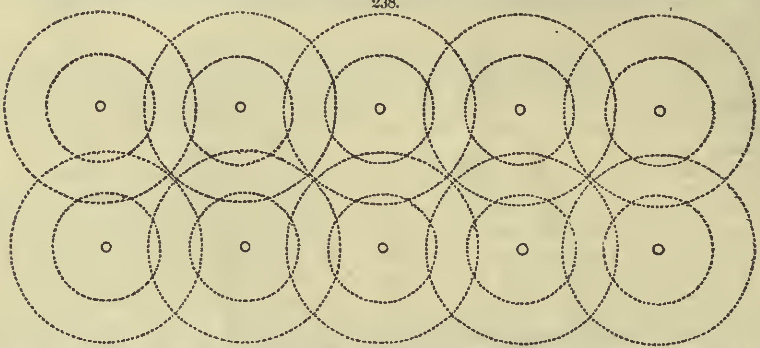
Blasting under water. The method of blasting rock under water, by the aid of the diving bell, as practised in Ireland, is as follows:—Three men are employed in the bell: one holds the jumper or boring iron, the other two strike alternately quick, smart strokes with hammers. When the hole is bored of the requisite depth, a tin cartridge filled with gunpowder, about two inches in diameter and a foot in length, is inserted and sand placed above it. To the top of the cartridge a tin pipe is soldered, having a brass screw at the upper end. The diving bell is then raised up slowly, and additional tin pipes with brass screws are attached, till the pipes are about 2 feet above the surface of the water. In the old practice the tube was filled with powder in a train, and fired; but in many instances the heat melted the solder of the pipe, and the water entering extinguished the fire. The improved method is to leave the tube empty. The man who is to fire the charge is placed in a boat close to the tube, and to the top of the tube a piece of cord is attached, which he holds in his left hand. Having in the boat a small portable furnace with small bits of iron red hot in it, he takes one of the bits of iron with a pair of nippers and drops it down the tube, which instantly ignites the charge and blows up the rock. A small part of the tube is destroyed next the cartridge, but the greater part, which is held by the cord, is reserved for future service. The workmen in the boat experience no shock by the explosion; but those who stand upon the shore or upon any part of the rocks, connected with those blasted, feel a very strong concussion. A certain depth of water above the charge—at least 12 feet—is necessary for safety. The workmen are generally down in the diving bell 5 hours in the day without coming up; and in the summer one set of men are down 10 hours one day, and 5 the next, and so on alternately. Figs. 237, 238, are sections and plans of means adopted by blasting to improve the navigation of the river Severn. Pipes $3\frac{1}{2}$ to 4 inches in diameter, $\frac{3}{16}$ an inch thick, and 9 feet long, were driven at

intervals of 6 feet from each other, through the gravel into the marl. These formed curbs for the boring of the holes into tho marl.

237.



238.



The holes were bored two feet below the proposed bottom of the dredging, as it was expected that each shot would dislocate, or break into small pieces, a mass of marl of a conical or parabolic form, of which the bore-hole would be the centre, and its bottom the apex, so that four adjoining shots would leave between them a pyramidical piece of marl, where the powder would have produced little or no effect. By carrying the shot-holes lower than the bottom of the intended dredging, the apex only of this pyramid was left to be removed, and in practice this was found to form but a small impediment, Figs. 237, 238.

The cartridges, or charges, were formed of strong duck or canvas bags, somewhat tapered at the bottom; these were filled with the required charge of powder, varying from 2 lb. to 4 lb., according to the depth of the marl; the weights of powder used for depths of 4 feet, 4 feet six inches, and 5 feet, were respectively about 2 lb., 3 lb., and 4 lb. The end of a coil of Bickford's patent fuse was inserted to the centre of the powder, and the neck of the bag was carefully gathered up round the fuse, and well tied with small twine. If the cartridge was small, it was then dipped into melted pitch, which had about one-fourth of tallow melted with it, or otherwise the melted pitch was ladled over it, till it was uniformly coated; in this state, the cartridges were hung to drain and stiffen. When hard, they were well rubbed over with tallow, and lastly powdered over with dry whiting. The tallow, whilst it ensured the stopping of any little cracks in the pitch, facilitated the passage of the cartridge down the hole; the whiting also prevented the pitch from adhering to any thing.

The charge was carefully pushed down into the hole by a wooden ramrod of suitable diameter, with the end rounded; the same instrument was used for ramming down the tamping. The material found to answer best for this purpose, was the small fragments of hard marl, separated by the action of the weather from the lofty escarpment at each of these shoals; this was gradually filled into the holes, and rammed solidly, till the bore was full up to the surface; the timber-dogs which held the pipes were then removed, the pipes were loosened from the marl, ropes were attached to the pipes and to the raft, or to some loose pieces of timber, and the shots were fired.

Mr. Maillefert bases his method of blasting beneath water without drilling, on the great resistance which the water offers to the passage of bodies through it, and which is as the squares of the velocity and the mass of water to be displaced; hence by placing a charge of gunpowder on or against the surface of the rock to be blasted, at a proper depth under water, and by firing off that charge, the considerable volume of gas which is almost instantaneously produced by such an explosion, would, in forcing its way through the water, meet with a resistance which would make it act in all directions, though in a different degree, somewhat like powder confined in a mine, and that the proportion of the concussion which would thus be directed against the rock, would be sufficient to disintegrate even the hardest and most tenacious kinds.

This conclusion proved perfectly correct in all cases where a proper proportion existed between the depth of water above the charge, the quantity and quality of the powder exploded, and the character of the rock.

The mode of procedure in carrying out this method of blasting is as follows:

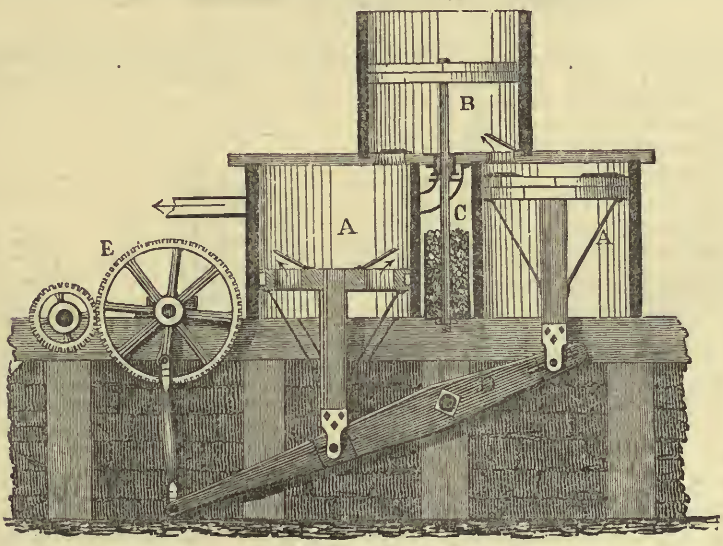
Having inserted an insulated conductor into a canister, made of tin or other suitable material, it is filled with gunpowder, and closed up so as to prevent access of the water. The cylinder is then lowered on the rock, from a boat or float, and by means of a rope or chain. Sliding along the guide-rod, it is placed exactly *on* the spot to be blasted, after which the guide-rod is withdrawn, the boat or float moved away far enough not to be injured by the agitation of the water consequent upon the explosion, which is effected by connecting the conductor with a galvanic battery, also placed at a suitable distance.

The results obtained in Hell-Gate, where nearly sixteen hundred cubic yards of the hardest rock (Gneiss) have been broken down and removed under very difficult circumstances, as an experiment, in less than seven and a half months, are sufficient to indicate what is to be expected from this method of blasting.

BLAST. The air introduced into a furnace.

BLAST MACHINES. In most metallurgical operations, the fire is urged to the proper degree of heat by forcing air into the fuel. This is done by machines which are driven by power. The pressure of the blast thus generated, and the velocity with which it enters the fuel, is greater or less according to the kind of fuel, and the effect which it is intended to produce. The most common blast machines are smith's bellows: these, however, are of limited use in smelting metals. Cylinder machines are constructed with a double and single stroke; wooden ones are generally of the latter, and the iron of the first description. In addition, there are machines with one, two, and three cylinders. One of the chief aims in constructing a blast machine must be to produce a uniform pressure. This is difficult, even with a regulator attached. Most of our blast machines do not furnish that uniformity which is required. Fig. 254 is a vertical section of a wooden blast machine; A, A, are two simple working cylinders, in each of the pistons of which there are two valves. On the top of these cylinders there are valves which lead to the regulator B, in which a piston moves that is connected by an iron piston-rod with the weight C. A balance beam D, sets both pistons A A in motion, and is itself moved by a crank pin and connecting-rod from the wheel E, which, again, is moved by a water-wheel or a steam-engine

254.

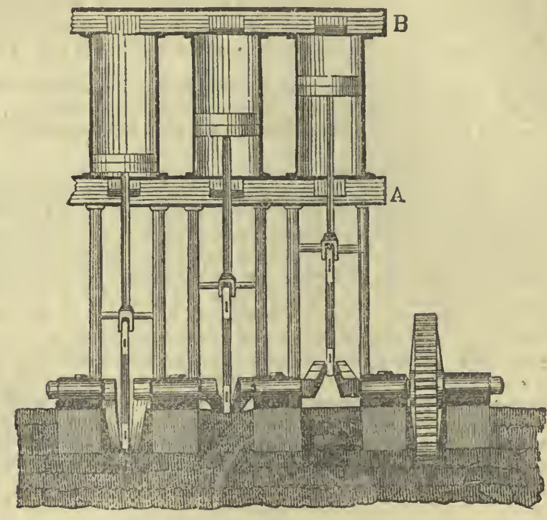


The whole machine is fastened to substantial timbers, which rest upon a good foundation of hewn stones. These cylinders and the regulator, are from 3½ to 5 feet in diameter, and not often of more than 3 feet stroke. The cylinders are constructed of segments of circles cut out of 1½ inch plank of dry ash wood, and well nailed and glued together. The fibre of the wood runs then parallel with the circumference. This form secures great solidity, prevents warping, and affords so much strength, when the thickness of the sides is at least three inches, that no iron hoops, or binders of any kind, are required. When the interior surfaces of the cylinders are well covered by a coating of fine plumbago, there is not much friction. Fat, grease, or oil of any kind, should not be put within a blast cylinder. Black-lead and glue, formed to a thin paste, is the best lubrication in this case. From 15 to 16 strokes per minute may be made with this machine. The packing of the pistons may be either of metal, wood or leather, although the latter is generally chosen. The valves are constructed of dry, light wood, and a close fit is secured by a piece of leather or of vulcanized rubber, which at the same time serves the purpose of hinges. In wooden cylinders the pressure cannot well be increased above ¾ of a pound to the square inch.

To obviate the use of a regulator, machines have been constructed with three blowing cylinders, the strokes being made to lap on to each other, as in fig. 255. Two hollow cast-iron beams, A, A, support the cylinders, and one serves in the mean time as the conductor of the blast, in the other the sucking

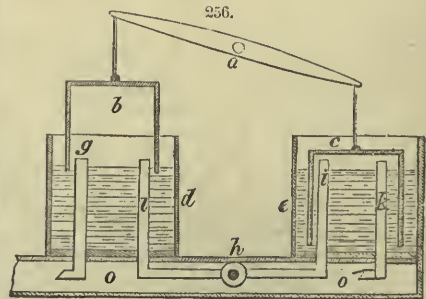
valves are located. At the top is a round pipe, B, running the length of the machine in which the blast is gathered from the upper parts of the cylinders. The upper and the lower pipes are connected by an upright pipe, and from this the blast is conducted to the desired spot at the furnaces.

255.



Another species of blowing-machine is the water-bellows. The nature of these machines will be readily understood by the help of the following diagram. The side figure is a vertical section of the machine. *a* is the fulcrum of the lever or beam, with two inverted vessels, *b* and *c*, suspended from its extremities; these vessels are open underneath, but air-tight above. *d* and *e* are two larger vessels, filled with water to the same level, in which the vessels *b* and *c* rise and fall alternately. *g h i* is a tube or pipe, which passes through the vessels *d* and *e*, and reaches above the surface of the water; at the extremities are two valves, which respectively open outwards into the inverted vessels, with a pipe at *h* open to the atmosphere. *k* and *l* are pipes passing through the bottom of *d* and *e*, and extending a little above the surface of the water; they are open at top, and have valves at bottom opening into the trunk *o*, to which the pipe is fitted which conducts the blast to the furnace. An alternating motion being imparted to the beam by a steam-engine or other first mover, the air passes up the tubes *g h i*, and fills each inverted vessel as they are successively drawn up out of the water; the descent of the inverted vessel closes the valves at *g* and *i*, and opens those at the bottom of the tubes *k* and *l*, through which the air is driven forward by the trunk *o*, and thus by the reciprocation of the beam, a continual blast is maintained through the trunk *o* and the tuyere of the furnace.

256.



A blast machine should be carefully constructed, in order to obtain the best results from it: iron ones are in all cases preferable. The piston is generally made similar to that of a steam engine. The form and position of the valves is one of the most important points connected with a blast machine. Air being elastic, expands when the pressure upon it is released: the compressed air ought to be driven out altogether at each stroke. We may locate the valves horizontally in the cylinder heads, even when the cylinders are vertical, as has been shown in fig. 254, but the weight of the valve is an objection to this. The vertical valve has a decided advantage. In whatever form the valve may be applied, waste room ought to be avoided. Valves should be as light as possible: the wooden valve lined with leather or vulcanized rubber, is for these reasons preferable to one of metal. In order to diminish the bad effects arising from the weight of valves, their number may be increased; this affords more space for the passage of air without increase of weight.

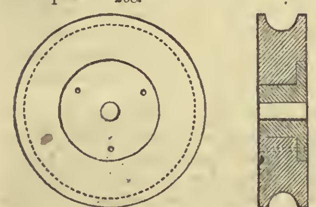
The size of a blowing cylinder depends upon the volume of air which is wanted. The stroke of the piston is generally limited by parts of the machinery depending on the locality and on the moving power; the number of strokes is also subject to considerations of economy and locality. A speed of 3 feet per second is considered an average velocity: multiply the velocity by the surface of the piston in feet, to obtain the quantity of air of the blast per second; but as blast is lost by leakage and waste room, multiply that result by $\frac{3}{4}$ for iron cylinders, and by $\frac{2}{3}$ for wooden ones. The quantity of air necessary in the consumption of a certain quantity of fuel, must be so calculated as to be sufficient to ox-

ldize it to the highest degree. It requires 100 pounds of air to convert 8·1 pounds of carbon into carbonic acid, in case all the oxygen is consumed. But this is not often accomplished; therefore 6 pounds may be assumed in reverberatories, which, in many instances, such as in reheating and roasting furnaces, is reduced to 5 and even 4 pounds of coal to 100 pounds of air. It has been ascertained at blast furnaces, that, when the quantity of fuel used during 12 hours in pounds is divided by 5, it shows the number of cubic feet of air required in one minute. Thus, when a blast furnace is to consume twenty charges of charcoal, of 15 bushels each, during 12 hours, and the charcoal weighs 20 pounds per bushel, the quantity of air which must be furnished to the furnace in each minute, of atmospheric density, is $\frac{15 \times 20 \times 20}{5} = 1200$ cubic feet.

Regulators. Piston blowers do not form a blast of uniform density; but as this is, in most cases, of the utmost importance, particularly in blast furnaces, regulators are attached to these machines. At present sheet iron right cylinders, of from 4 to 8 ft. in diameter, and from 15 ft. to 40 ft. in length, are generally adopted as the most suitable and best forms. The thickness of the sheet iron is not often more than $\frac{1}{8}$ of an inch, frequently less; the heads are formed of cast-iron, or of sheet-iron and stiffened by wood and iron screws. This chamber, or regulator, is provided with a safety-valve, to insure it against bursting from excessive pressure. The blast is introduced at one end, and tapped at the same or the opposite end. The equalization of the blast is produced by the elasticity of the air. It is easily understood, that in a large chamber the pulsations of the blast machine are not so strong as in a small one, but the size must be limited for reasons of economy. As a general rule, it is established that the capacity of this regulator should be from 10 to 18 times that of one of the blast cylinders; but harm ensues if it is larger. For charcoal furnaces it should have a capacity at least 20 or 25 times that of the cylinder; it may be smaller for anthracite and coke furnaces.

BLOCKS, in the Navy and Marine Architecture, a species of pulley very extensively used for moving heavy weights, by means of ropes or chains passing over the pulleys; also occasionally in architectural and other works. A block consists of one or more pulleys, called sheaves, which are generally formed of lignumvitæ, or some hard wood inserted between cheek pieces, forming what is called the shell of the block, and turning upon a pin passing through the shell and the centres of the sheaves. Blocks are suspended by straps, either of rope or iron; the latter are called iron-strapped blocks, and have frequently a swivel-hook. A combination of two blocks, one of which is attached to the load to be raised, is called a tackle, and the power is to be estimated by the space through which the fall (which is that part of the rope to which the power is applied) passes, compared with the space through which the load is raised, deducting for friction, which is great, owing to the rigidity of the ropes, and the small diameter of the sheaves; these, for nautical purposes, are necessarily limited by considerations as to weight and space.

268.



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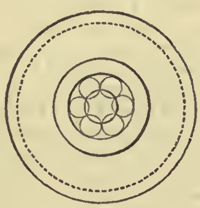

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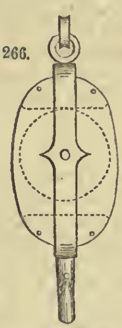

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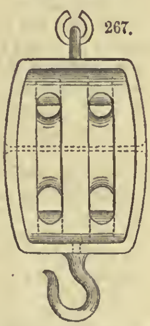

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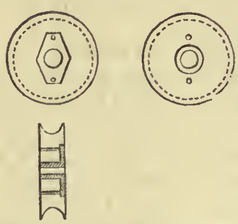


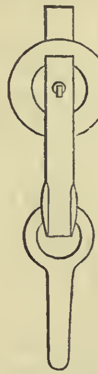
The shells are almost invariably of wood, in the smaller blocks being made of a single piece of wood, with a channel morticed for the reception of the sheave. Formerly almost all blocks were made in this manner, and beautiful and effective machines were made at the Woolwich Dock, by Mr. Bennet, for forming the different parts of a block, but in this country the shells are now made in pieces, and bolted or riveted together at the top and bottom. Each block is furnished with a strap or band of rope or iron, encircling it and terminating in an eye or hook. A block having a fixed position is called a *standing* block, whilst one which is attached to the weight and hoisted with it, is called a running block. A *Snatch* block consists of a single sheave with a notch cut through one side of the shell to allow the rope to be lifted in or out without inserting it end first. Figs. *266, 267, is a form of block in common use for shipping in this country. Its construction is easily understood from the figure. The block is double, or with two sheaves, and the shell consists of three large pieces with four pieces inserted between them at the top and bottom of the block. The whole is firmly bound with an iron strap. Figs. 268, 269, represent the construction of sheaves, with iron bushings, the collars and rivets being counter sunk. Fig. 270 is an elevation of a sheave showing an arrangement of friction pulleys or rolls, to admit of an easier motion.

Figs. 271, 272, represent a front and side elevation of a single block complete, constructed according to Waterman and Russell's Patent.† Figs. 273, 274, represent a like view of a double block of the same Patent with the shells removed.

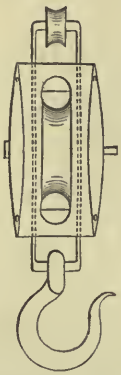
*Jas. Carroll, Burling Slip. † Burr & Co., South st., N. Y.

The peculiarity of these blocks consists in the iron straps being closely adjusted to each side of the sheave, so as barely to have its discs free of lateral friction, and then being made to combine in a solid iron bar, at just sufficient distance from the periphery of the sheave to leave the rope space to run without chafing, while the combined bar or straps extend sufficiently without the block to form the hooks at each extremity. These blocks are in many respects to be preferred to the old-fashioned blocks, whose iron straps are a mere hoop around the wood of the block, leaving all the space of the wood between

273.



272.



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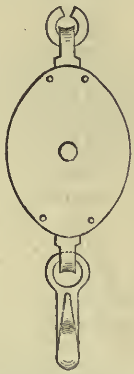

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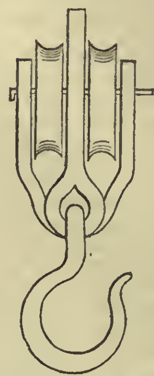


this hoop and the sheave for the pin to spring or bend. Thus a much larger pin is required, which of course will produce more friction, and besides, it cannot be hardened to inflexibility or be made of hardened steel, lest it should break; from the leverage which the weight on the sheave exerts on the support of the pins, the iron at the *outside* of the blocks. If the pin should bend, the friction it produces would not only be increased by cutting the corners at the discs where it passes through the sheave, but the sheave is exceedingly liable to be canted to the right or left, and to suffer in consequence a lateral friction, from contact with the wood of the block. But the patent iron-strapped blocks admit of no such leverage. The straps being close by the sides of the sheave, preclude the bending of the pin in the least, and give only the advantage of dead weight to the power that could be exerted to break it. Indeed, this weight must be sufficient to cut the pin square off by dead force before it will give way, and this without the advantage of any bend or twist whatever. The pins of these blocks are of hardened steel. At their introduction, these blocks were tested at the Navy Yard, Washington, and were found superior to their own blocks; they are now much used in every service.

There is a species of blocks termed "*Dead-eyes*," which are used for tightening or setting up, as it is called, the standing rigging of ships. It consists merely of a circular block of wood, with a groove on its circumference, round which the lower end of the shroud, or an iron strap, is fastened: three holes passing through the face, (ranged in a triangle,) to receive the laniard or smaller rope, which forms a species of tackle for tightening the shrouds. There are no sheaves in the dead-eye, but the edges of the holes are rounded off to prevent cutting the lanyard; but this very imperfectly answers the purpose; as from the roughness of the grain of the wood, which is usually elm, and from the stiffness of the rope, the laniard renders with difficulty; and from the great strain to which it is subjected, it is frequently broken. A very simple and effectual improvement has been made in this respect, by inserting a half-sheave of lignumvitæ into each of the holes which causes the laniard to render with greater facility, and the shroud to be set up in half the usual time.

BLOWING MACHINES. See Blast.

BLOW-OFF COCKS AND PIPES. See Engines.

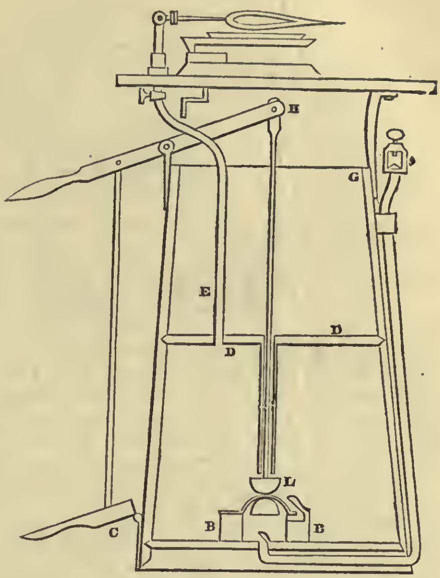
BLOW-PIPE. An instrument for exciting intense combustion upon a small scale; it is extensively used in many branches of the arts, and also in philosophical experiments upon metallic substances. In its simplest form it is merely a conical brass tube, curved at the small end, in which is a very minute aperture; and a stream of air being urged through it by the mouth against the flame of a lamp or candle, a heat equal to that of the most violent furnaces may be produced. The body intended to be operated upon should not exceed the size of a peppercorn, and should be supported upon a piece of well-burned, close-grained charcoal, unless it be of such nature as to sink into the pores of the charcoal, or to have its properties affected by its inflammable quality. Such bodies may be placed in a small spoon made of pure gold, silver, or platinum. Many advantages may be derived from the use of this simple and valuable instrument. It is portable; the most expensive materials, and the minutest specimens of bodies, may be used in the experiments; and the whole process is under the eye of the observer. In the blow-pipes used by enamellers, glass-blowers, and others, the current of air is maintained by a small pair of double bellows.

Early in the present century, Dr. Hare, of Philadelphia, made a most important improvement in the blow-pipe, by substituting for the flame of a lamp that arising from a mingled current of oxygen and hydrogen, of which we shall treat presently.

The Hydrostatic Blow-pipe consists of a cask, divided by a horizontal diaphragm into two parts D D. From the upper apartment, a pipe of about 3 inches diameter (its axis coincident with that of the cask) descends, until within about 6 inches of the bottom. On this is fastened by screws, a hollow cylinder of wood B B, externally 12 inches in diameter, and internally 8 inches. Around the rim of this cylinder a piece of leather is nailed, so as to be air-tight. On one side a small groove

is made in the upper surface of the block, so that a lateral passage may be left when nailed on each side of the groove. This lateral passage communicates with a hole bored vertically into the wood by a centre-bit; and a small strip of leather being extended so as to cover this hole, is made, with the addition of some disks of metal, to constitute a valve opening upwards. In the bottom of the cask there is another valve opening upwards. A piston-rod, passing perpendicularly through the pipe from the handle H, is fastened near its lower extremity to a hemispherical mass of lead L. The portion of the rod beyond this proceeds through the centre of the leather which covers the cavity of the wooden cylinder; also through another mass of lead like the first, which, being forced up by a screw and nut, subjects the leather between it and the upper leaden hemisphere to a pressure sufficient to render the juncture air-tight. From the partition, an eduction-pipe E is carried under the table, where it is fastened by means of a screw to a cock which carries a blow-pipe, so attached by a small swivel-joint as to be adjusted in any required direction. A suction-pipe passes from the opening covered by the lower valve, under the bottom of the cask, and rises vertically close to it on the outside, terminating in a union-joint for the attachment of any flexible tube which may be necessary. The apparatus being thus arranged, and the cask supplied with water until the partition is covered to about the depth of 2 inches, if the piston be lifted, the leather will be bulged up, and will remove in some degree the atmospheric pressure from the cavity beneath it; consequently the air must enter through the lower cavity to restore the equilibrium. When the piston is depressed, the leather being bulged in an opposite direction, the cavity beneath it is diminished, and the air being thus compressed, forces its way through the lateral valve into the lower compartment of the cask, which compartment being previously full of water, a portion of the fluid is pressed up through the pipe into the upper apartment. The same result ensues each time that the stroke is repeated, so that the lower compartment soon becomes filled with air, which is retained by the cock until its discharge by the blow-pipe is necessary. Dr. Hare, in his oxy-hydrogen blow-pipe, did not mix the gases in his gas reservoir, but supported the flame of the hydrogen by a current of oxygen issuing from different jets. Subsequently, it was found that the heat produced was materially affected by the *proportions* in which the gases were mixed, and that the greatest intensity of heat was obtained by two volumes of hydrogen united with one of oxygen; and various attempts were made to mix and *burn* the gases in their due proportion, but with little success, until the important improvement effected in the instrument by Dr. Clarke, Professor at Cambridge. This improvement consisted in first mixing the gases in a bladder, in the exact proportions to form water, and afterwards condensing them in a strong iron chest, by means of a condensing syringe. To an opening at the end of this chest he attached a great number of layers of fine wire gauze, through which the mixed gases were driven by their elastic force into a small tube, at the end of which they were inflamed. By this arrangement he obtained a much greater heat than had been effected by Dr. Hare's invention, and was enabled to make a great number of experiments highly interesting to science. Unfortunately, however, for the general adoption of his plan, it was soon found that his instrument was unsafe to use; *that the wire gauze would not prevent the explosion of the gases;* that in several cases, when used by the most experienced and cautious operators, the instruments were burst. The explosions were tremendous, and resembled the bursting of a bomb, the fragments of the iron chest being scattered with great force in all directions. After trying various plans to render the invention safe, the Doctor, as a protection, had the iron chest placed behind a brick wall at the back of the operator, the gases being conveyed through a tube passing through the wall. In this state the instrument remained, until Mr. Goldsworthy Gurney applied himself to its improvement, and after numerous experiments, which are highly interesting, and are fully detailed in his published lectures, he succeeded in producing an instrument unattended with the slightest danger in its use, and admirably adapted both for scientific investigation, and for various operations in the arts. The annexed engraving is a representation of the instrument. A is the safety-chamber; B a water-trough, through which the gas is made to pass from the gasometer D by the cock C, through a tube which reaches to the bottom of the water-trough; E is a cock fitted into the neck of the same, from which it is thrown out should an explosion take place on the surface of the water. F is a gage, to indicate the necessary height of the column of water in the trough. G is a transferring bladder, which is made to screw and unscrew to and from the stop-cock H, for the purpose of supplying the gasometer with gases, which may be charged and recharged at pleasure, by an assistant, during its action, so as to keep up the most intense flame for any length of time. A valve is placed between the gasometer and the transferring bladder, which prevents the return of the gas. I I is a light wooden or stiff pasteboard cap, which combines sufficient strength with great lightness, so that in case an explosion of the gasometer should happen, it is merely thrown a short height into the air, by the force breaking the strings which connect the cap to the press-board. To these strings are attached

275.



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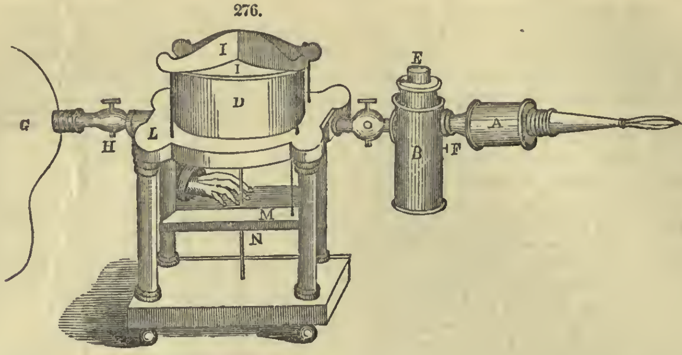


small wires which pass through the table of the instrument, as at L, into the press-board below, where they are secured; this press-board is kept in a horizontal position by the stand, so that when the requisite pressure is given to it, the cap I I is brought to bear equally on the gasometer D. The gasometer bladder (or silk bag) is tied to a piece of bladder, which screws into a long tube laid into and across the table, which permits it to be unscrewed at pleasure from the body of the instrument, and immersed in water when it requires softening, affording also the means of fixing on another bladder, if any accident should render it necessary. The stop-cock of the charging bladder G is fixed to one end of the tube just described, and the stop-cock of the water-trough on the other end. To operate with this instrument, pressure by the hand is applied to the press-board, which draws down the cap I I on the gasometer D, and forces the gas which it contains through the stop-cock C, and through the water-tube and safety-chamber A, to the jet at the end, where it is burned. When the pressure on the press-board is too slight, or when the hand is taken off, the flame returns into the safety-chamber, and is extinguished. When it is required to suspend the operation, the hand need only be taken off the pressing-board; the water in the trough acts as a self-acting valve in preventing the escape of gas from the instrument, and saves the necessity of turning the stop-cock. A silk tube is attached to the end of the tube before described, in the water-trough, which prevents the splashing of the water, sometimes occasioned by unskilful management. We omitted to state that the safety-chamber A is filled with numerous disks of very fine wire gauze closely packed, and should the flame be driven in, which will sometimes happen, it will not enter the bag or reservoir D, but will explode above the surface of the water in the chamber B, merely driving out the cork. An improvement has, however, been since introduced in the construction of the safety-chamber, by Mr. Wilkinson, by which the retrograde motion of the flame appears to be effectually prevented, and a much larger jet may be employed than heretofore with perfect safety. This improvement consists in filling the chamber A with alternate layers of wire gauze and of asbestos, previously beaten with a mallet, and pulled out to resemble floss silk. Mr. Wilkinson received from the Society of Arts a silver medal for his communication on the subject, and we understand that Mr. Hemming has recently made some further improvements in the construction of the instrument. We must here advert to the wonderful effects produced by the oxy-hydrogen blow-pipe, which almost instantaneously reduces the hardest and most refractory substances. Gun-flints are instantly fused by it, and formed into a transparent glass; china melts into a perfect crystal. All kinds of porcelain are readily fused, previously assuming a beautiful crystallized appearance. Rock crystal is quickly melted, giving out a beautiful light. Emerald, sapphire, topaz, and all the other precious stones, melt before it into transparent glassy substances. Barytes, strontian, lime, and alumina, exhibit very striking and beautiful phenomena. Magnesia fuses into hard granular particles, which will scratch glass. The metals, even platina, are *all* quickly fused by it; and all descriptions of stones, slates, and minerals, are melted, sublimed, or volatilized, by its all-subduing power.

BLOW-PIPE. Dr. Hare's Hydro-oxygen; *On certain improvements in the Construction and Supply of the Hydro-oxygen Blow-pipe, by which Rhodium, Iridium, or the Osmiuret of Iridium, also Platinum in the large way, have been fused.* By Robert Hare, M. D., Professor of Chemistry in the University of Pennsylvania.

While a pupil of my predecessor, Dr. Woodhouse, in the year 1801, having observed that a jet of hydrogen when inflamed in atmospheric air, of which only one-fifth is oxygen, was productive of a heat of pre-eminent intensity, I was led to infer that in combining with pure oxygen, the gas in question ought to produce a temperature at least five times as great. This led to the contrivance of two modes of producing a jet consisting of a mixture of hydrogen with oxygen. Agreeably to one mode, the gaseous currents, meeting like the branches of a river, were made analogously to form a common stream. This object was accomplished by means of perforations drilled in a conical frustrum of pure silver, so as to converge until met by another shorter perforation, commencing at the opposite surface, and so extended as to join them at the point of their meeting. The other mode was that of causing one tube to be within another, so as to be concentric, the outer tube being a little the longer of the two; the latter being employed for hydrogen, the former for oxygen.

In the year 1814, this last-mentioned mode was improved, so as to have the means of securing, by adjusting screws, the concentricity of the tubes, and varying the distance of the orifice of efflux of the inner tube from that of the other.

The constructions employed in 1801, were described and published in a pamphlet, and afterwards

republished in Tillock's Philosophical Magazine, vol. xiv., and in Annals de Chymie, vol. xiv. At the same time an account was given of the fusion of pure lime and magnesia, and of the fusion of platinum. Subsequently, in a paper published in the Transactions of the American Philosophical Society, it was mentioned that I had volatilized platinum.

About the year 1811, Professor Silliman, in a memoir read before the Connecticut Academy of Sciences, gave an account of a series of experiments, in which the experiments which I had performed were repeated, and many additional fusions made. I had adverted to the intensity of the light produced during the exposure of lime to the flame. Alluding to the heat and light, my words were, "the eyes could not sustain the one, nor the most refractory substances resist the other." The intensity of the light was still more insisted upon by Silliman.

My experiments were also repeated by Mr. Rubens Peale, during many successive years, at the Philadelphia Museum, for the amusement of visiters.

About the year 1813–14, it was ascertained, at the laboratory of Dr. Parrish, that a bladder being supplied with a mixture of hydrogen and oxygen, in due proportion, and punctured by a pin, while subjected to compression, on igniting the resulting jet, the gas within the bladder did not explode. Of course, a burning jet of flame thus created was found competent to produce, while it lasted, the same effect as when otherwise generated by the same gaseous mixture.

Soon after this result was obtained, Sir Humphrey Davy discovered, that if a lamp flame be completely surrounded by a gauze of fine wire, it may be introduced into an inflammable gaseous mixture without causing it to explode. This was ascribed to the refrigerating influence of the metal, keeping the gaseous mixture below the temperature requisite for inflammation. Hence it was inferred, that if a mixture of hydrogen and oxygen, while condensed within a suitable receiver, was allowed to escape through a capillary metallic tube, so as to form a jet, this might be made to burn without communicating ignition to the portion remaining in the receiver.

By means of an apparatus contrived agreeably to this idea, Dr. Clark, of Cambridge, England, repeated the experiments, made many years before by Silliman and myself, without any other reference to ours, than such as was of a nature to do injustice. An exposition of the invalidity of Dr. Clark's pretensions to originality was made in Silliman's Journal for 1820, vol. ii., and in Tillock's Philosophical Magazine for 1821, vol. lvii.

The light produced by the hydro-oxygen flame with lime having been observed by Lieutenant Drummond, of the British Navy, was ingeniously proposed by him as the means of illumination in lighthouses, and has been, in consequence, subsequently used as a substitute for the solar rays, in an instrument known as the hydro-oxygen microscope, which is a modification of that which has been called the solar microscope. The name of Drummond light has consequently been given to a mode of illumination, which I originally produced as above stated.

The instrument which was used by Professor Silliman and by Rubens Peale, was that above described as having two perforations meeting in one. In this form it was, I believe, employed by Dr. Hope, of Edinburgh, and Dr. Thompson, of Glasgow, who both treated it as my contrivance, anteriorly to the publication of Dr. Clark's memoir.

The other form, consisting of two concentric pipes, was modified by a Mr. Mangham, with the view of producing a lime light for the microscope above alluded to. When I saw Mr. Mangham at the Adelaide gallery in 1836, he treated this instrument as mine, in another form. I was surprised afterwards to learn that he had obtained a premium for this modification from the British Society for the Encouragement of Arts, without any allusion to the original inventor.

After my return from Europe in 1836, I was very much in want of a piece of platinum of a certain weight, while many more scraps than were adequate to form such a piece were in my possession. This induced new efforts to extend the power of my blow-pipe; and after many experiments, I succeeded so as to fuse twenty-eight ounces of platinum into one mass.

Although small lumps of platinum had been fused by many operators, with the hydro-oxygen blow-pipe, as well as myself, it had not, up to the year 1837, been found sufficiently competent to enable artists to resort to this process. I am informed by Mr. Saxton, that some efforts which were made while he was in London were so little successful, that the project was abandoned. There was an impression that the metal was rendered less malleable when fused upon charcoal, as in the experiments alluded to. This is contradicted by my experiments, agreeably to which fused platinum is as malleable as the best specimens obtained by the Wollaston process, and is less liable to flake. The celebrated Dr. Ure, on seeing the platinum in the forms of wire, of leaf, and plate, said that there was no one in Europe who could fuse platinum in such masses. He also alleged that it had been found so difficult to weld platinum, that no resort was had to that process. In this I concur, having had the welding tried by a skilful smith, both with a forge heat, and with a heat given by the hydro-oxygen blow-pipe. An incorporation of two ingots was effected on their being hammered together, when heated nearly to fusion; but on hammering the resulting mass cold, a separation took place along the joint by which the ingots were united.

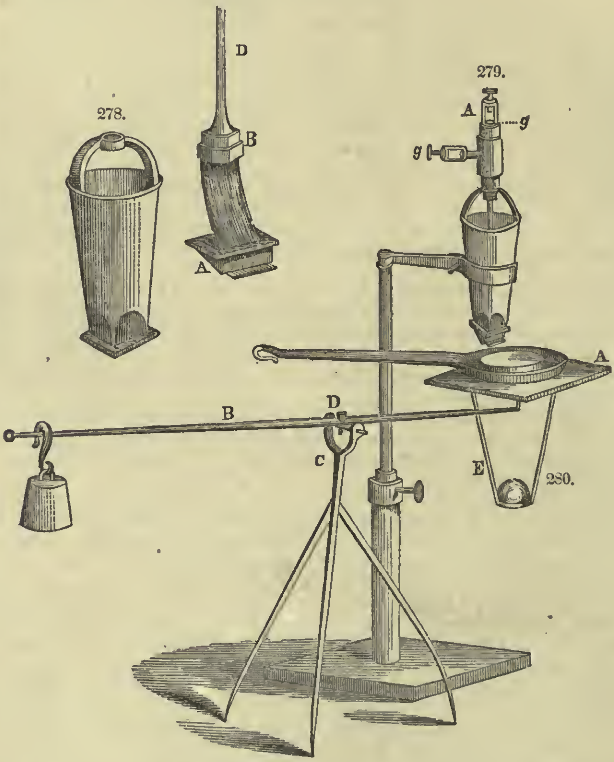
The difficulty seems to arise from the rapidity with which the platinum becomes refrigerated. It seems to have a less capacity for heat than iron, and, not burning in the air as iron does, has not the benefit of the heat acquired by iron from its own combustion with atmospheric oxygen.

Latterly, by means of the instrument and process which it is my object here to describe, I have been enabled to obtain malleable platinum from the ore directly, by the continued application of the flame. From some specimens of platinum I have procured as much as ninety per cent. of malleable metal. The malleability is not inferior to that of the best specimens obtained, by reducing it to the state of sponge, through the agency of aqua regia and sal ammoniac. There is, however, a greater liability to tarnish, arising, probably, from the presence of a minute portion of palladium.

Of the fusion of iridium and rhodium, I have already given an account in the Bulletin of the Society, which was subsequently embodied in an article prepared for Silliman's Journal for October last, 1846.

It remains now to give an account of the apparatus employed in the fusion of platina on a large scale.

Fig. 277 represents the association of fifteen jet-pipes of platina with one large pipe, D B, at their upper ends, so that their bores communicate, by means of an appropriate brass casting, with that of the large pipe, the joints secured by hard solder. Their lower extremities are made to protrude about half an inch from a box A, of cast brass, their junctures, with the appropriate perforations severally made for them, being secured by silver solder. They come out obliquely in a line along one corner of the box, an interval of about a quarter of an inch alternating with each orifice. By means of flanges, the brass box is secured to a conical frustum of copper, Fig. 278, so as to form the bottom thereof, while the pipe, extending above the copper case, is screwed to a hollow cylinder of brass, A, Fig. 279, provided with two nozzles and gallows screws *g g* for the attachment of appropriate hollow knobs, to which pipes are soldered, proceeding from the reservoirs of oxygen and hydrogen. Cocks are interposed by which to regulate the emission of the gases in due proportion.



In connecting the pipes conveying the gases with the brass cylinder, A, Fig. 279, care should be taken to attach that conveying oxygen to the upper nozzle, while the other, conveying hydrogen, should be attached to the lower nozzle; since, by these means, their great difference in density tends to promote admixture, which, evidently, it must be advantageous to effect.

The object of surrounding the jet-pipes with water, by means of the copper box,* is to secure them against being heated to such a degree as to cause the flame to retrocede and burn within them, so as finally to explode within the cylinder, A, *g g*, Fig. 279. It is preferable to add ice or snow to the water, in order to prevent undue heat.

Fig. 280 represents a moveable platform, A, of cast-iron, wholly supported upon the point of the iron lever D B, which is curved towards the extremity under the platform, so as to point upwards, and to enter a small central conical cavity made for its reception. The lever is supported by a universal joint upon the fulcrum C, so that by means of the sliding-weight at one end, the platform and its appurtenances are counterpoised at the other. The platform is kept in a horizontal position by the cannon-ball, supported in a sort of iron stirrup terminating in a ring, in which the ball is placed. Upon the platform is situated an iron pan with a handle, holding the brick, on a cavity in which, as already

* Since the engraving was made, I have preferred to use water-tight boxes, with gallows screws and nozzles, situated one near the bottom on one side, the other on the opposite side near the top. By means of the lower nozzle, a pipe is attached, communicating with a head of cold water, the other being so situated as to carry the water into a waste pipe, or large tub; a circulation may be kept up during the whole time that the operation is going on.

As a support, a brick of kaolin is used, having an oblong elipsoidal depression on the upper face for the reception of the metal to be fused.

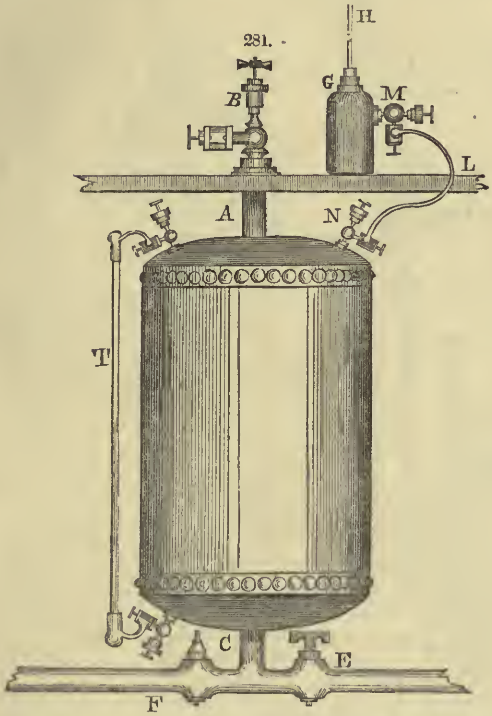
mentioned, the metal is supported. The apparatus being duly prepared, and connected with the supply pipes, the hydrogen is first allowed to escape, and then the oxygen, until the ignition has attained apparently a maximum. The accomplishment of this object may, of course, require the adjustment of either cock several times, especially where there is any decline in the pressure either of the one or the other gas in its appropriate reservoir.

By means of the handles of the lever and of the pan, the operator is enabled to bring the metal into the position most favorable for the influence of the heat, while his hands and face are sufficiently remote to render the process supportable. In fusing any quantity, not being more than four ounces, the platform may be dispensed with, the handle of the pan being held in one hand of the operator, while by the other the cocks may be adjusted.

When the blow-pipe of fifteen jets, or any larger, may be employed, and the platform is necessarily resorted to, the cocks must be adjusted by an assistant.

Fig. 281 represents a cask made of boiler-iron, three-sixteenths of an inch thick, so as to resist an enormous pressure. The joints are secured by riveting, as in constructing high-pressure boilers.

281.



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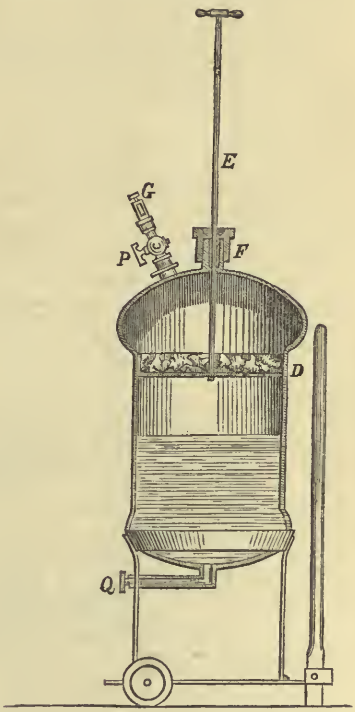

This cask communicates with the hydrant-pipes, so called, by which our city is supplied with water, of which the pressure varies from a half to more than two atmospheres, say from seven to thirty pounds per square inch, according to the number and bore of the cocks from which the water may be flowing at the time, for the consumption of the community. Hence, experiments, while using this head, are best made towards bedtime, or between that time and sunrise. The vessel is filled with water by opening a cock F on one side of the pipe C, and allowing the air to escape through the valve-cocks B. Being thus supplied, the cock F closed, and a communication with a bell-glass, into which oxygen is proceeding from a generating apparatus, being made by means of a flexible leaden tube, on opening the valve-cock B and the cock E the water will run out, and be replaced by gas from the bell. This process being continued till the iron cask is sufficiently supplied with gas, the cock E must be shut. Whenever the gas is wanted for the supply of the blow-pipe, it is only necessary to establish a communication between the valve-cock B and the upper gallows-screw, Fig. 279, of the cylinder A, and to open the cock F so as to admit the water to press upon the gas, the efflux being regulated by B, or preferably by a cock of the ordinary construction, one of which kind should be interposed at a convenient position between the valve-cock B and cylinder A.

T represents a glass tube, which, by due communication with the interior, shows the height of the water, and consequently the quantity of gas in the vessel.

G H represents a gaging apparatus, consisting of a cast-iron flask, of about a half a pint in content, and a glass tube of about a quarter of an inch in bore, which should be at least five feet in height. The tube is secured air-tight into the neck of the flask, so as to reach nearly to the bottom within. The flask is nearly full of mercury. Under these circumstances, when a communication is made, by a leaden pipe between the cavity of the flask and that of the reservoir, an equilibrium of pressure resulting, the extent of the pressure is indicated by the rise of the mercury in the tube.

In order to generate hydrogen for the supply of a reservoir like that represented by the preceding figure, I have employed the vessel represented by Fig. 282. This vessel, by means of a suitable aperture, susceptible of being closed by a screw-plug, is half filled with diluted sulphuric acid. Being furnished with a tray of sheet copper D, punctured like a coal-sieve, and supported by a copper sliding-rod E, strips of zinc are introduced in quantity equal to the capacity of the tray. The sliding-rod passes through a stuffing-box F, at top of the reservoir, so that the operator may, by lowering or raising the tray, regulate or suspend the reaction between the zinc and its solvent, accordingly as the supply of hydrogen is to be produced, suspended, increased, or diminished.

The communication with the reservoir is opened and regulated by means of the cock P, furnished with a gallows-screw G for the attachment of a leaden pipe, as above described, in the process for supplying the reservoir with oxygen.

Another apparatus for producing a supply of hydrogen, is represented in Fig. 000. It consists of two

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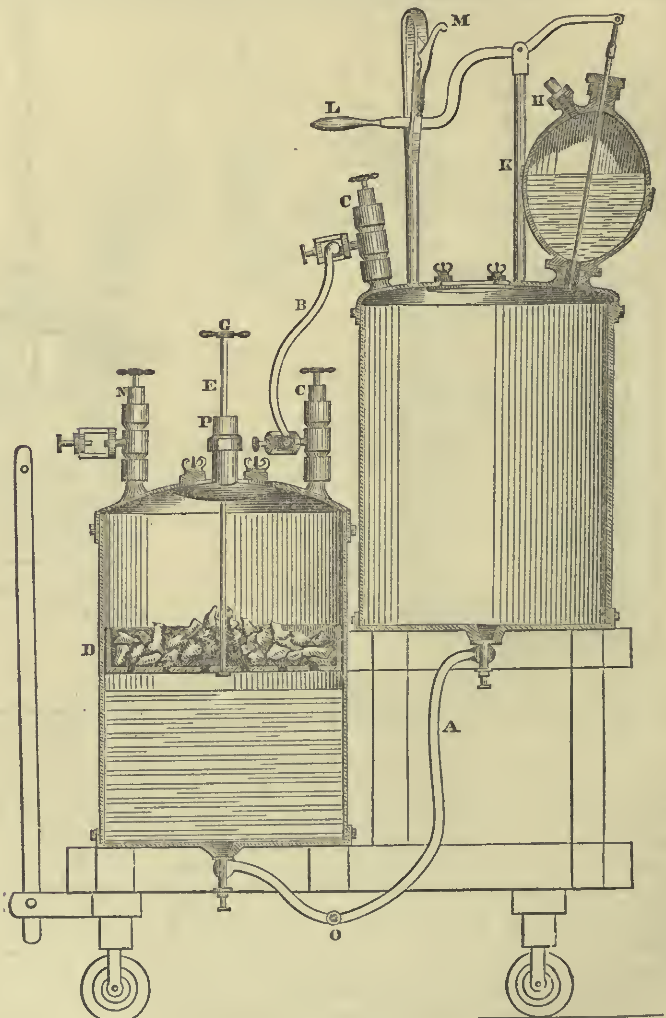


similar vessels of boiler-iron, each capable of holding forty gallons. They are lined internally with copper, being situated upon a wooden frame, so that the bottom of one is two-thirds as high as the top of the other. The upper portion of these vessels communicate by a leaden pipe B, of about half an inch bore, furnished with a cock, while the lower portions communicate by another leaden pipe of a bore of 1½ inches.

The upper vessel is surmounted by a globular copper vessel, of about twelve inches in diameter which, from its construction, renders it possible to introduce an additional supply of concentrated acid while the apparatus is in operation, without reducing the pressure within the reservoir, by permitting the excess above the pressure of the atmosphere to escape. This object is accomplished as follows:—

The valve at the end of the rod, attached to the lever L, being kept shut by the catch M, the screw-plug H removed, the acid is introduced through the aperture thus opened. In the next place, the plug being replaced, and the valve depressed by means of the lever and rod, so as no longer to close the opening, which it had occupied, the acid descends from the chamber into the cavity of the vessel beneath it. The valve is of course restored to its previous position as soon as the acid has effected its descent.

The lowermost vessel is furnished with a perforated copper tray, supported by a copper sliding-rod, in a way quite analogous to that already described in the case of the copper reservoir. It is also supplied with zinc and its solvent in like manner, being made half full of the diluted sulphuric acid. Of course, on contact being produced between the zinc and its solvent, the generation of hydrogen will take place. So long as the communication between the upper portions of the two vessels is open, the gas will extend itself into both, occupying the whole of the upper vessel, and that half of the lower one which is unoccupied by the liquid. But if, in this way, the pressure reaches to two atmospheres, as indicated by the gage, on shutting the communication through the pipe B, the pressure in the inferior vessel will augment, that in the superior vessel remaining as before, but the liquid will consequently begin to pass out of the inferior vessel through the pipe A, and thus may lessen the contact between the acid and zinc, and finally suspend it altogether. Meanwhile the gas in the upper vessel being condensed to nearly half its previous bulk, the pressure will be nearly four atmospheres. It will, in fact, always be nearly double that which existed before the pipe B was closed.

In order that nearly the whole of the acid shall be expelled from the inferior vessel, the tray must be depressed till it touches the bottom of that vessel.

The pressure being four atmospheres at commencement, as soon as, by means of a pipe attached to the valve-cock N, an escape of gas is allowed, the acid is forced again upon the zinc, and thus prevents a decline of pressure to any extent sufficiently to interfere with the process.

The gases may be used from a receiver in which they exist, in due proportion, safely by the following means. Two safety-tubes are to be made, not by Hemming's process exactly, but as follows:—A copper tube, silver soldered, of which the metal is about the eighth of an inch in thickness, is stuffed with the finest copper wire, great care being taken to have the filaments straight and parallel. The tube is then to be subjected to the wire-drawing apparatus, so as to compress the tube on its contents until the draught becomes so hard, as that it cannot be pushed farther without annealing. The stuffed tube thus made is to be cut into segments, in lengths about equal to the diameter, by a fine saw. The surfaces of the sections are to be filed gently with a smooth file. By these means, they appear to the naked eye like the superfices of a solid metallic cylinder. Brass caps being fitted on these sections, they are to be interposed by soldering, at the distance of a foot or more, into the pipe for supplying the jet. Under these circumstances, the posterior section, becoming hot, may allow the frame to retrocede; but the anterior section being beyond the reach of any possible combustion, and remaining cold, will not allow of the retrocession; and as soon as the flame passes the first section, the operator, being warned, will of course close the cock, and subject the posterior section to refrigeration before proceeding again.

But this plan of operating may be rendered still more secure by interposing a mercury bottle, or other suitable iron vessel, half full of oil of turpentine, between the reservoir and safety-tubes, as in the arrangement of a Woulfe's bottle. A leaden pipe proceeding from the reservoir is, by a gallows-screw, attached to an iron tube which descends into the bottle, so as that its orifice may be near the bottom. The leaden pipe communicating through the safety-tubes with the jet-pipe, is attached to the neck of the bottle. Thus the gaseous mixture has to bubble through the oil of turpentine in order to proceed through the safety-tubes to the jet-pipe. If, while this process is going on, the flame should, by retrocession, reach the cavity of the bottle, exploding in contact with the turpentine, a compound is formed, which is, *per se*, inexplosive from the excess of carbonaceous matter. Meanwhile the shock, acting on the surface of the oil, drives it into the bore of the iron tube, and thus, both by its chemical and mechanical influence, renders it utterly impossible that the flame should reach the cavity of the reservoir.

BOBBINET MACHINERY, is the name of machines which are intended for manufacturing a peculiar net-like texture, whose constructure is inferred from that of the pillow-made or bone-lace, and which, in its most simple intertwisting, is known by the name of *plain bobbinet* and *quillings*. The simple intertwisting of the plain bobbinet has been altered in various manners, and thus have been produced new kinds of texture, partly very different in appearance from that of the plain bobbinet; and in recent time furnishing very fine fancy articles, much in demand. They are termed *figured bobbinet* in the following description, which treats chiefly of the most common and most recent systems of bobbinet machines.

The machines for manufacturing quillings, and which are known by the term *stripe-machines*, work quillings or edgings from ½ to 4 and 6 inches in breadth, and of considerable length. A great many edgings, connected with and by the side of each other, thus forming one broad piece, are worked simultaneously, and are subsequently separated. As the quillings are, as it were, to be edged at both borders, for the sake of fastness and durability, this edging and intertwisting of the several quillings require particular contrivances in the machines, which thus, according to the different systems applied to them, are more or less complicated.

Those for manufacturing the figured bobbinet are in general narrow; that is to say, there can be worked only pieces of inconsiderable breadth by them.

This is owing partly to the circumstance, that older machines, originally intended for manufacturing pieces six or eight quarters of a yard wide, have been arranged for figured bobbinet, to make them still fit for use in any way; and partly to the fact that the making of figured bobbinet is by far more difficult than that of plain bobbinet, and that it requires the most eager attention and skilfulness of the operative. To the latter it would be almost impossible to overlook broad pieces of this kind, or the work would go on so slowly that such an arrangement could be of no great avail.

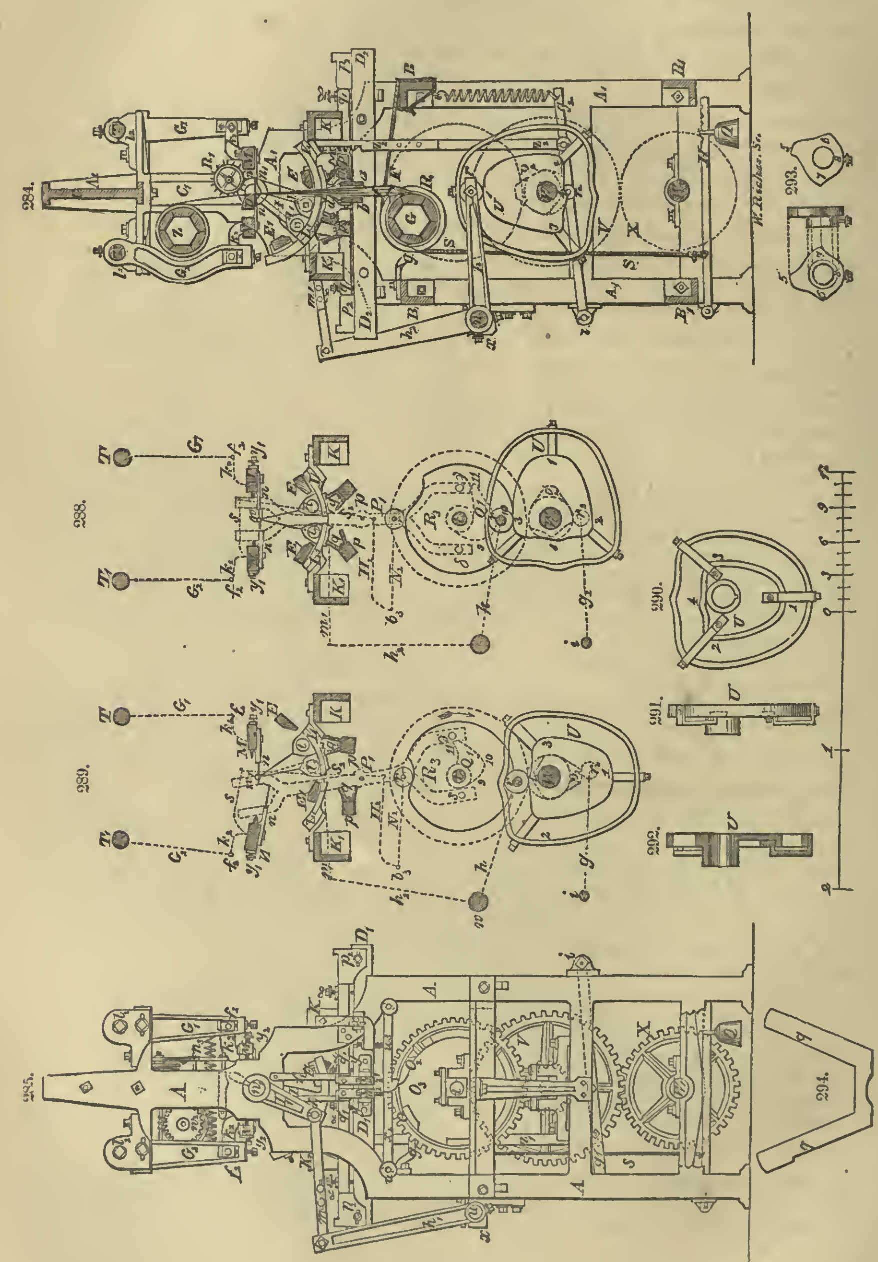
Alphabetical Survey and Explanation of the Letters in the Figs. 284 *to* 394.

A, right side-frame, Figs. 285 and 286.
A_1, left side-frame, Figs. 284, 286, and 287.
B, fore front-frame, Figs. 284, 303, 317.
B_1, back front-frame, Figs. 284, 303, 317.
C, joist joining the uppermost parts of the side-frames, Fig. 286.
C_1, pillars screwed on C, and bearing the sockets of the lace-beam A, Fig. 286.
D, rounded iron bars across which the texture passes on its way to the lace-beam, Fig. 286.
D_1, D_2, cross-beams at the right and left sides of the frame, Figs. 284 and 285.
E, front pusher-bar, Figs. 284, 288, and 289.
E_1, back pusher-bar, Figs. 284, 288, and 289.
F, a kind of reed composed of perforated brasses for the warp-threads, Figs. 284 and 286.
F_1, steel springs of the hold-fast contrivance, Fig. 357.
G, warp-beam, Fig. 284.
G_1, G_2, lever-arms of the point-bars, Figs. 284, 285, 288, and 289.
H, lever bearing the weight-stone R, Figs. 284, 286, and 287.
H_1, lever moving the front point-bar, Fig. 287.
H_2, lever moving the back point-bar, Figs. 287, 288, and 289.
I, cradle-arms, Figs. 284, 285, and 286.
I_1, cradle-pieces, Figs. 284, 285, and 286.
K, front bolt-bar, Figs. 286, 288, 289, 300, and 303.
K_1, back bolt-bar, Figs. 287, 288, 289, and 303.
L, front comb, Figs. 284, 288, and 289.
L_1, back comb, Figs. 284, 288, and 289.
M, front point-bar, Figs. 284, 285, 288, 289.
N, back point-bar, Figs. 284, 285, 288, and 289.
N_1, crowbar of the front point-bar, Figs. 286 and 287.
N_2, crowbar of the back point-bar, Figs. 288 and 289.
O, socket-frame in the midst of the machine. P, socket-frame at the side of the machine. Both are fastened to B and B^1, and bear the sockets of the lockers, Figs. 315 and 317.
P_1, forked bars for both point-bars, Figs. 287, 288, and 289.
Q, weight-stone for the tension of the warp, Figs. 284, 285, 286, and 287.
Q_1, lifting-thumb acting on the forked bar P_1, Figs. 288 and 289.
R, grooved disks for the cords or strings S, Fig. 286.
R_1, large rowels, Fig. 284.
R_2, shell-wheel of the front point-bar, Fig. 286.
R_3, shell-wheel of the back point-bar, Figs. 286, 288, and 289.
S, cords or strings for the tension of the warp, Figs. 284, 285, 286, and 287.
S_1, support of the front point-bar, Fig. 287.
S_2, support of the back point-bar, Figs. 287, 288, and 289.
T, T_1, shafts to which the lever-arms G_1 and G_2 are fastened, Figs. 284, 288, and 289.
U, large heart-shaped disk to bring about the swinging movement of the pusher-bars, Figs. 284, 288, 289, and 290.
U_1, similar disk in Figs. 358 and 359.
V, great spur-wheel with 48 cogs at the principal axis W, Figs. 285 and 286.
W, principal axis of the machine, Figs. 284, 286, 288, and 289.
W^1, driving axis of the machinery for the thong-disk Y, Figs. 284, 285, and 287.
X, dented wheel at the axis W_1, with 36 cogs, Fig. 285.
Y, thong-disk at the axis W_1, Fig. 286.
Y_1, thong of the disk Y, Fig. 286.
Z, the lace-beam, Fig. 284.

a, front guide-bar, Figs. 284, 331, 332, 303, 317, &c.
a_1, adjusting screw for the lateral movement of the front guide-bar, Figs. 331, 332, and 333.
a_2, adjusting screw for the lateral movement of the back guide-bar, Fig. 333.
b, back guide-bar, Figs. 284, 303, 315, 317, and 333.
b_1, b_2, curved stays through which the adjusting screws *a* and a_2 pass, Figs. 331 and 333.
b_3, common pivot of the levers H and H_2, and of the crowbar N and N_2, Figs. 287, 288, and 289.
c, front series of guides, Fig. 284.
c_1, projecting bolt, through which the supporting screws *d* and d_2 pass, Figs. 331 and 333.
c_2, c_3, adjusting screws of the levers H_1 and H_2, Fig. 287.
d, back series of guides, Fig. 284.
d_1, d_2, supporting screws of the guide-bars, Figs. 331, 333.
e, middle stay of the bolt-bars, Figs. 300, 301, 302.
f, warp-threads, Figs. 284, 335, 336, and 360.

f_1, steel springs for pushing back the guide-bars, Figs. 285, 295.
f_2, pivots on which the point-bars turn, Figs. 285, 288, 289.
g, socket-irons of the warp-beam, Fig. 284.
g_1, g_2, lever-bars for the lockers, Figs. 285, 288, and 289.
h, lever-arm at the midst of the axis w, Figs. 358 and 359.
h_1, h_2, lever-arms at the ends of the axis w, Figs. 358, 359, and 284, 285, 288, 289.
i, pivot of the lever-bars g_1 and g_2, Figs. 284, 285, 288, 289.
k, k_1, weft-threads, Fig. 360.
k_2, curved arms, to which the pivots f_2 of the point-bars are fixed, Figs. 285, 288, 289.
l, front carriage-line, Figs. 284, 288, 289.
l_1, back carriage-line, Figs. 284, 288, 289.
l_2, sockets of the shafts T and T_1, Figs. 285, 286.
l_3, sockets of the shafts w in Figs. 358, 359.
m, m_1, drawer-bars of the lever-arms h_1 and h_2, Figs. 358, 359, and 284, 285, 286, 288.
m_2, adjusting screw for the lateral movement of the front comb, Figs. 286, 300, 301.
m_3, adjusting screw for fixing the back comb, Figs. 286, 288, 300, 301.
n, point-pieces, Figs. 284, 286, 288, 289.
n_1, n_2, split sockets of the guide-bars, Figs. 304, 305 a, in the midst of D_1 and D_2, and of the machine.
n_3, spiral-spring of the point-bars, Fig. 285.
o, comb-shifting disk at the shaft t, Fig. 286.
o_1, ratchet-wheel of the front guide-bar, Fig. 286, left side.
o_2, ratchet-wheel of the back guide-bar, Figs. 285, 286.
o_3, comb-shifting disk at the shaft t, right side, Fig. 286.
p, locker-bar, Figs. 284, 288, 289, 309.
p_1, bolts or rails to which the adjusting screws m_2 and m_3 are fixed, Figs. 300, 301, 286.
p_2, socket-pieces at D_1 and D_2, Figs. 284, 285, 286.
q, locker, Figs. 284, 288, 289, 309.
q_1, supporting arms or stays of the bolt-bars, Figs. 284, 285, 287, 300, 301, 302, 303
q_2, screws for supporting the bolt-bars, Fig. 317.
r, sliding roller of the large heart-shaped disk U, Figs. 284, 288, 289
$(r,)$ sliding roller of the large heart-shaped disk U_1, in Figs. 358 and 359.
r_1, roller of the locker-disk v_1, Fig. 286.
r_2, roller of the locker-disk v_2, Fig. 286.
r_3, rowels at the bar D, Fig. 286.
r_4, sliding roller of the shell-wheels R_2 and R_3, Figs. 288 and 289.
s, arms by which the point-bars are connected with the supporting bars S_1 and S_2, Figs. 287, 288, 289
s_1, s_2, dented wheels at the axis W, Fig. 286.
t, shafts to which are fixed all ratchet-wheels and disks, Figs. 285, 286, 288, 289.
t_1, t_2, dented wheels at the axis t, Fig. 286.
u, pivot on which the pushing levers x_1 and x_2 move, Fig. 285.
u_1, angular lever of the front guide-bars, Fig. 295.
u_2, angular lever of the back guide-bars, Fig. 295.
u_3, pushing lever of the front comb, to the right, Fig. 286.
u_4, pushing lever of the front comb, to the left, Fig. 286.
v, motive power or quarter-wheel of the lockers, Figs. 284, 311, 312.
v_1, locker-disk for the back locker, at the axis W, Fig. 286.
v_2, locker-disk for the front locker, at the same axis, Figs. 284, 286, 288, 289.
w, shafts to which the lever-arms h, h_1 and h_2, are fixed, Figs. 386, 289, 358 and 359.
w_1, shafts to which the cradle-arms I, and cradle-pieces I_1 are fixed, Figs. 284, 285, 286, 287.
w_2, dented wheel of the lace-beam, Fig. 285.
x, socket of the shaft w, Fig. 284.
x_1, pushing lever of the front guide-bar, Figs. 286 and 295.
x_2, pushing lever of the back guide-bar, Figs. 286 and 295.
x_3, x_4, angular levers for pushing the bolt-bars, Figs. 285 and 287.
y, bolt or rail, through which the common peg of the angular levers u_1 and u_2 are put, Fig. 295.
y_1, adjusting screw of the point-bar, on which the upper fork of the bar S_1 is acting, Figs. 288, 289
y_2, adjusting screws of the point-bar, which strike against the side-frame A and A_1, Fig. 285.
z, a trigger, Fig. 286.
z_1, z_2, dented bars for the lockers, Figs. 284, 287, 311, 312, 314.

α, foot-screws of the bolt-bars, Figs. 284, 285, 286, 287, 300, 303.
β, notch in which the middle stays e are running, Fig. 317.
ϑ, δ, iron pegs at the lower fork of the bar S_1, Figs. 288 and 289.



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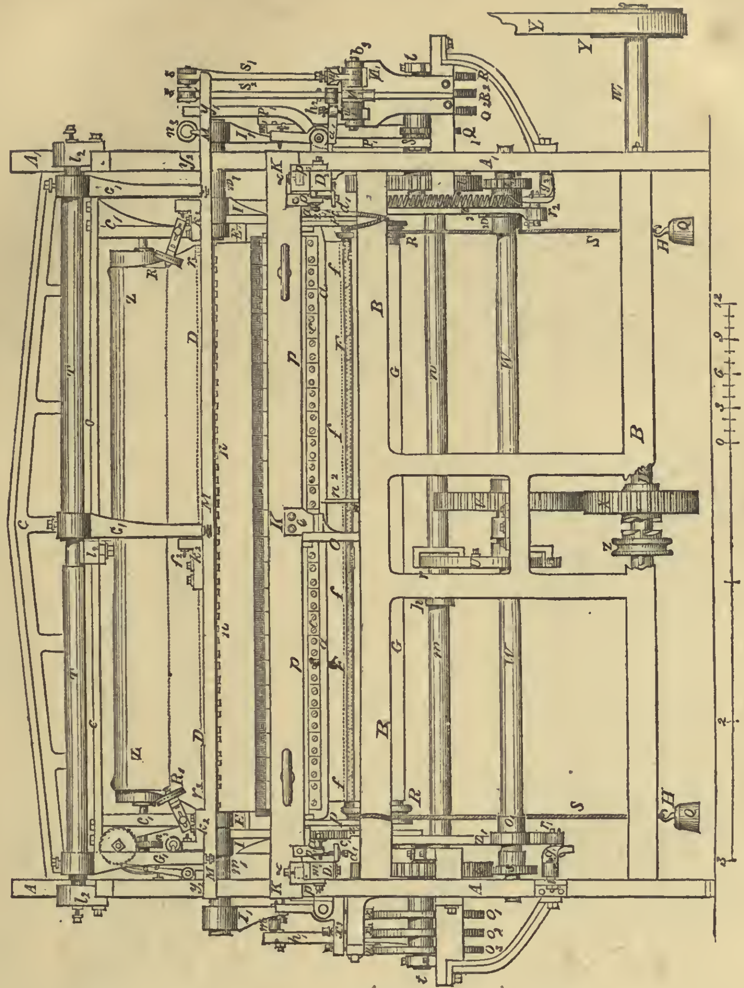

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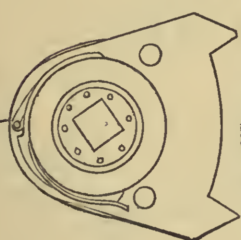

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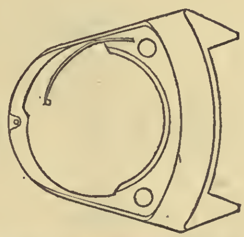

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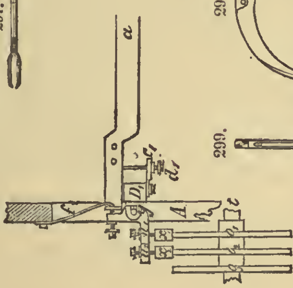

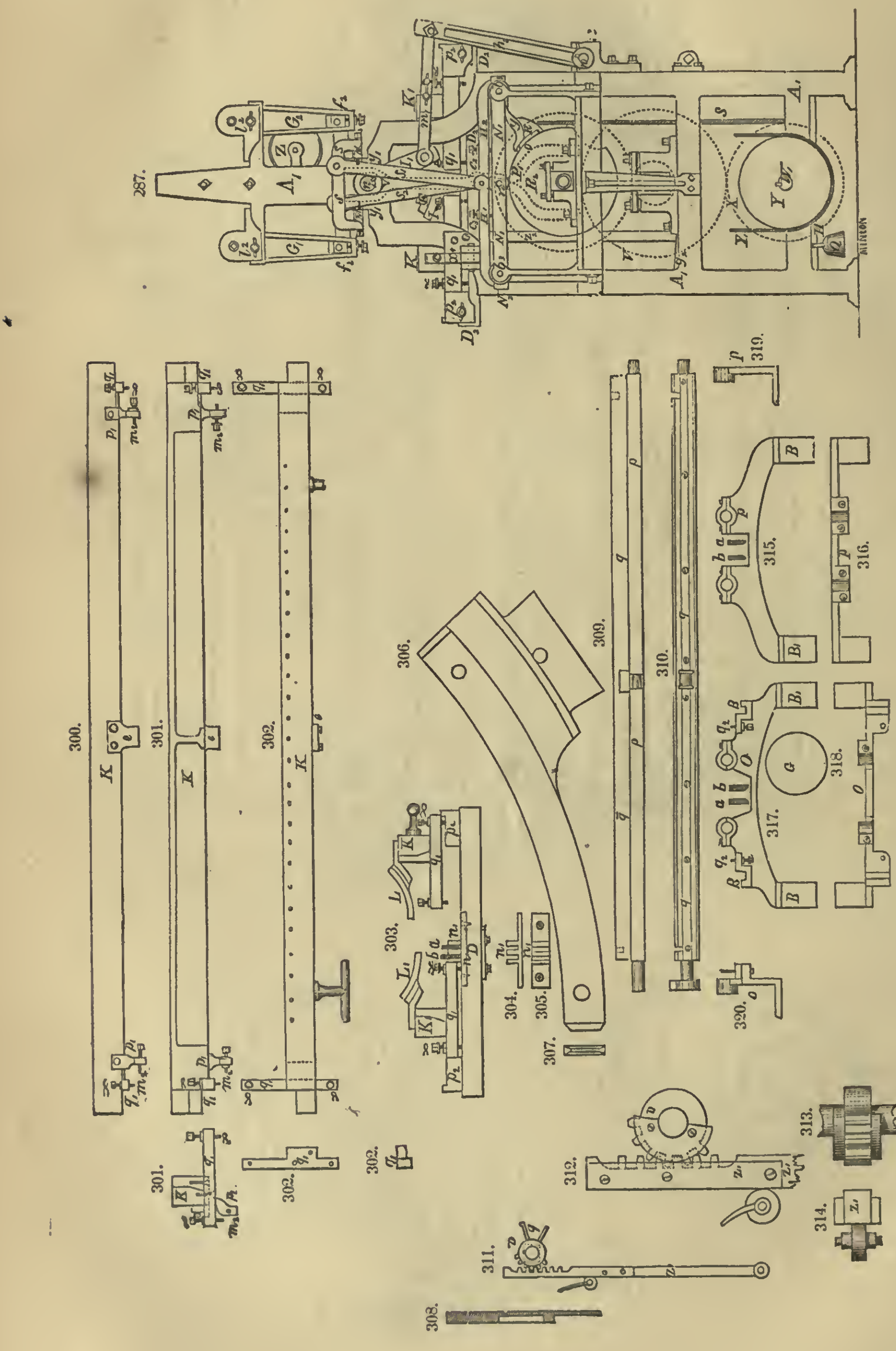
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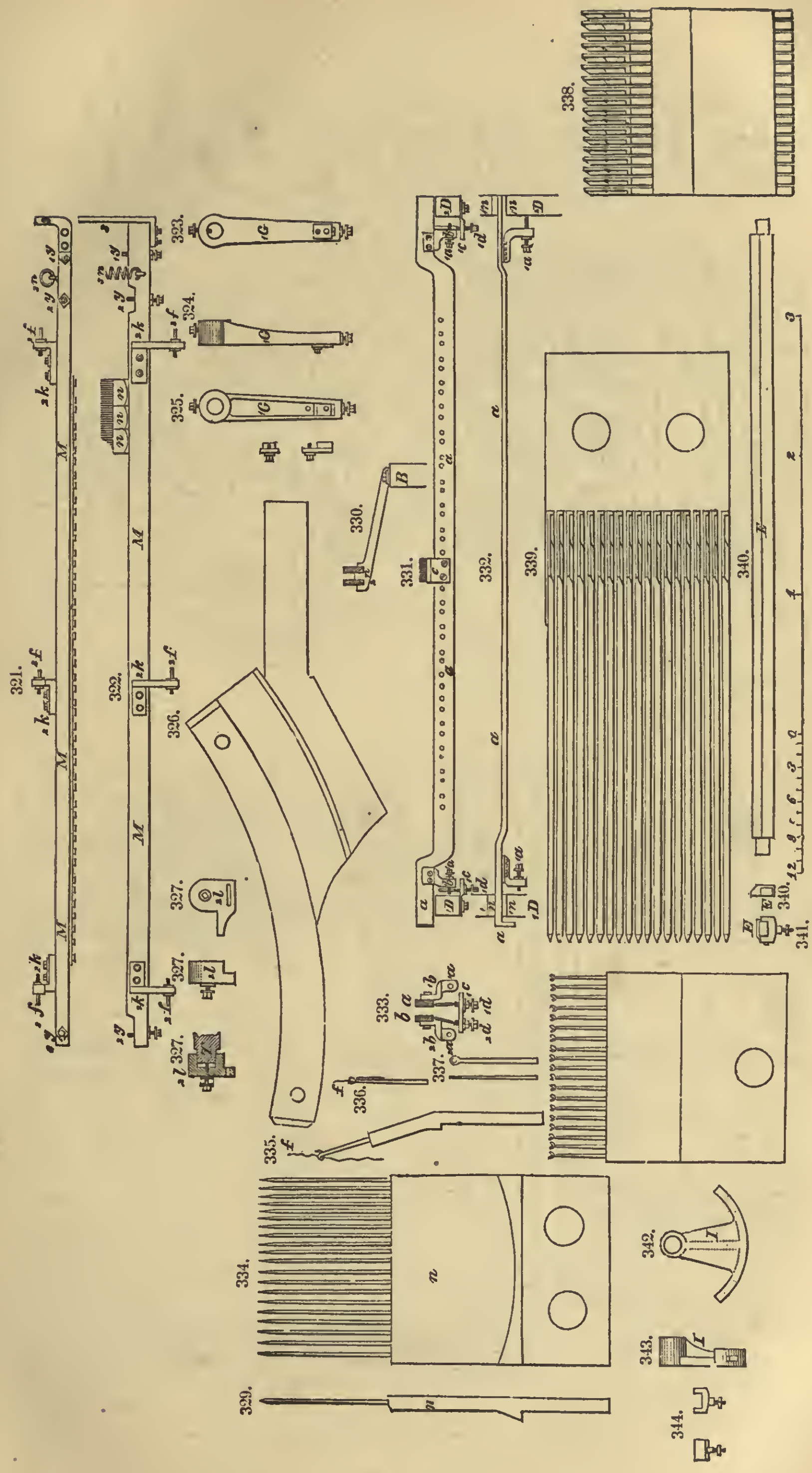
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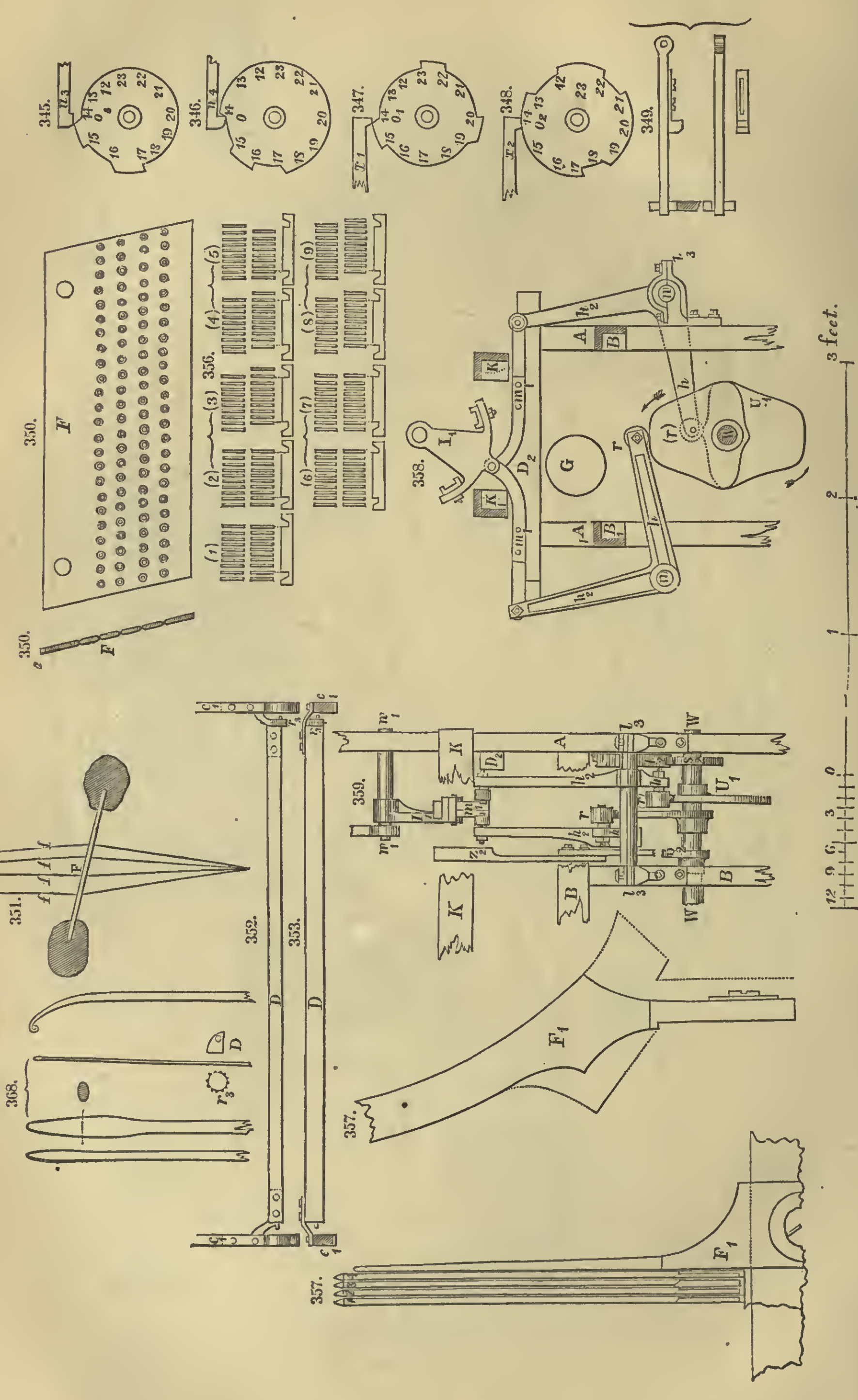
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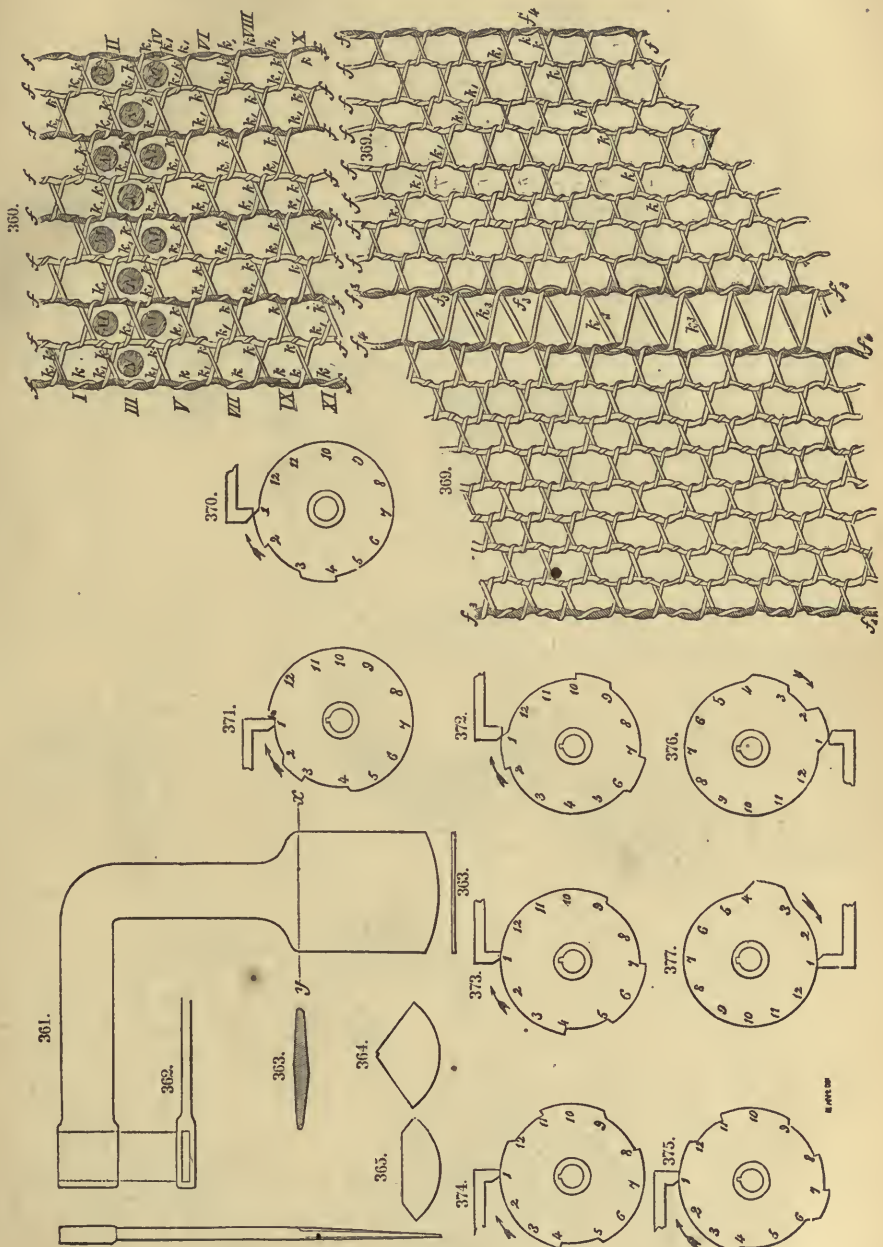

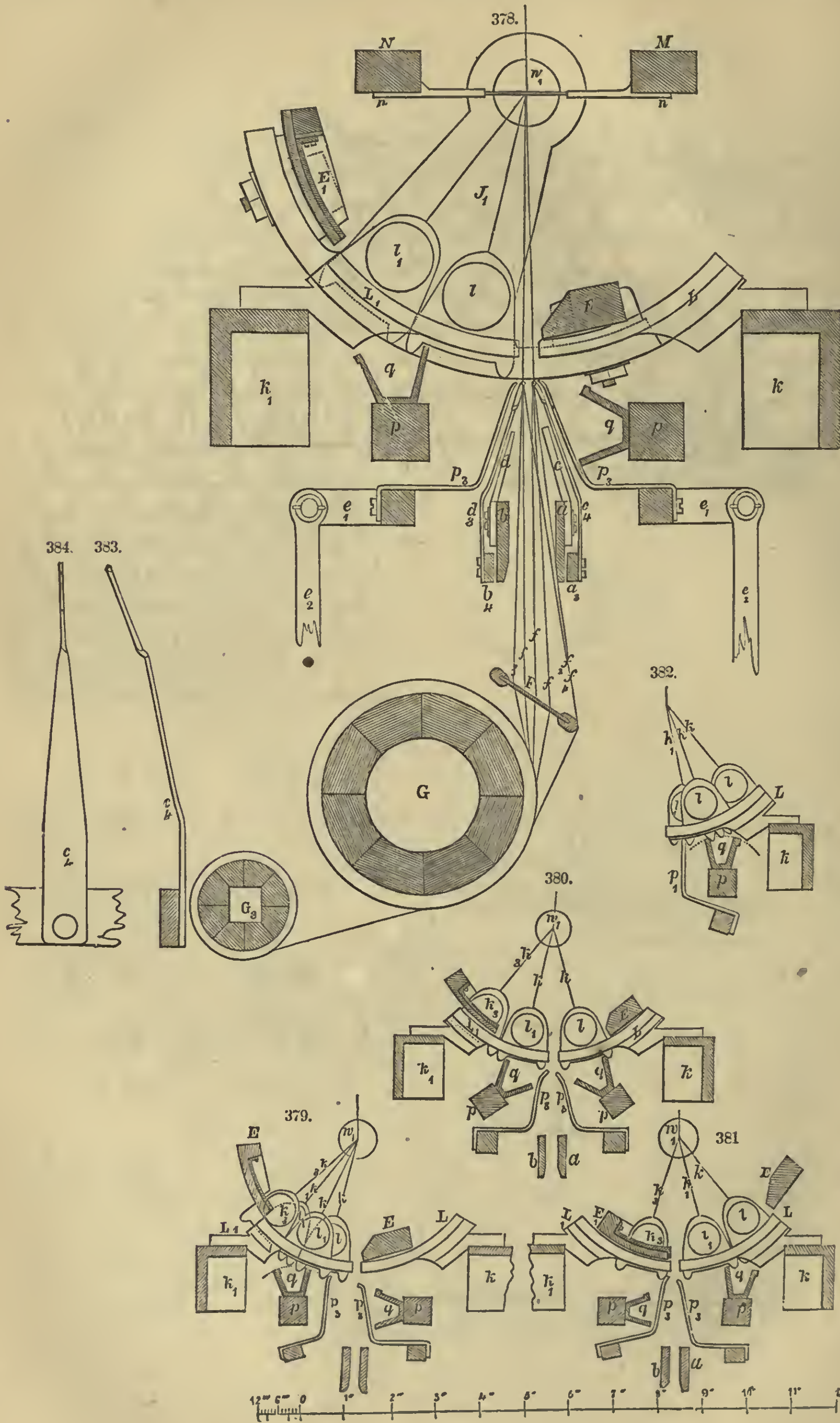
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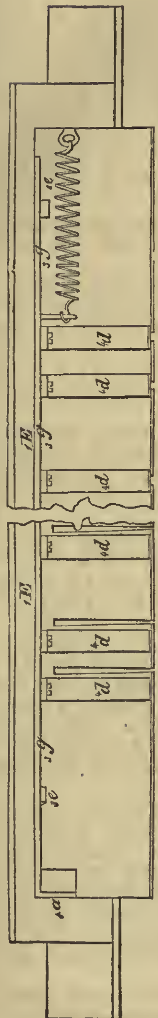

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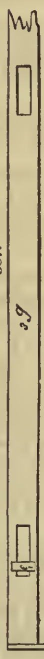

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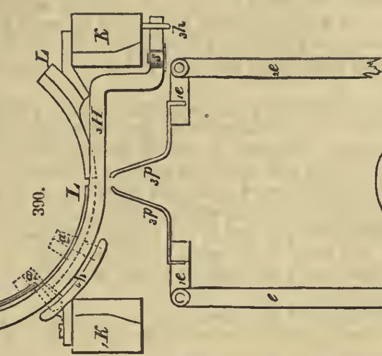

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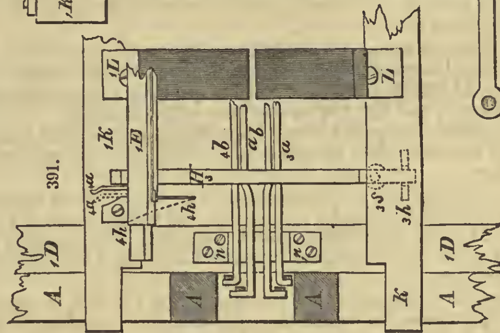

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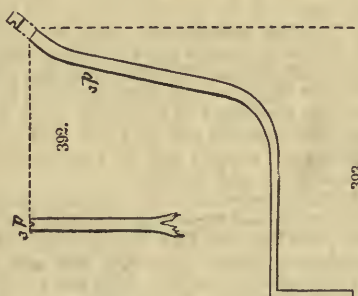

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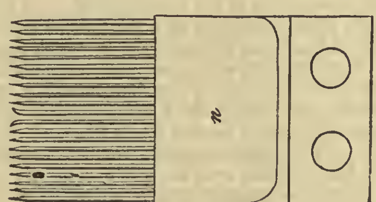


394.

Machines for manufacturing broad plain Bobbinet.

The latest and most approved construction of these machines is according to the *double-locker* system. Machines of this system can be arranged for any breadth of the piece, and are working for weeks, and even months, with great precision and quickness, without any interruption which might be produced by irregularity in the mechanism. Being commonly of considerable breadth, the motive power must be very strong; therefore it is driven either by water or steam.

In the following, we give a description of a machine for webs 8 quarters wide, constructed according to the *double-locker* system, and illustrated by Figs. 284 to 375, in the most careful manner. The illustrations are given with all particulars required, which may enable the mechanic to draw upon a large scale from them.

The machine for manufacturing plain bobbinet, though being the most simple of all bobbinet machines, belongs, however, by its construction to the most complicated ones. Its web is represented by Fig. 360 on a large scale. One and the same thread is marked along its way by the same letter. The threads f are extended up and down, or proceed downwards in serpentine lines, while the two other sets of threads k and k_1 proceed from the right to the left, and from the left to the right in slanting directions. By this, the twisting and interlacing of the threads is produced. The perpendicular threads in the figure, which are parallel to the border, may be regarded as the warp, and the two sets of slanting threads as the weft, in comparing bobbinet with a common web. The straight warp-threads receive their twist from the tension of the weft-threads, twisted obliquely round them alternately to the right and left.

This seemingly simple union of the threads requires, however, a very complicated mechanism, which must be understood before the operation of the machines can be comprehended, and their result examined more closely.

At the chief frame A A, B B, C, are shown all parts of the machine. (See Figs. 284 to 287.) Fig. 284 shows the machine near its centre in transverse section; Fig. 285 gives an end view of the right side of the machine, before which the operative has his ordinary place. Fig. 286 gives a front view of the fore side, and Fig. 287 an end view of the left side.

Two and two opposite sides of the frame are completely equal to each other, viz: A and A_1, B and B_1; all four are united by screw-bolts. The joist C, Figs. 284 and 286, binds the upper ends of A, A^1 together.

The warp of the web consists, as has already been mentioned, of parallel running warp-threads, which are coiled round the warp-beam. In proportion to the proceeding of the fabrication, the warp is unwound, while at the same time the finished lace is wound upon the lace-beam. The lace-beam is placed above the warp-beam, as may be seen by Z and G in Fig. 284, where they are shown in transverse section.

The ends of the *warp-beam* (represented in Fig. 284, in transverse section, and with the warp wound upon it) are provided with strong rollers or disks; and its pivots run in iron sockets, which are fastened to B_1, and in the figure marked by g. The disks R are grooved to receive the cord S, one end of which is fastened at B, while the other end runs vertically downwards, and is fastened to the lever H.

This lever turns on a pivot at the post B_1, and its fore end bears the weight Q. This contrivance serves to keep the warp in due tension while being wound off the warp-beam. This unwinding takes place in four rows of warp-threads, (see Fig. 284,) for which purpose the single threads pass the eyes of a kind of *reed* F. Figs. 284, 286, and 350, 351, consisting of single pieces of latten-plate, called *brasses*, and placed one by one into the grooves of two long staves, bound together at the ends and in the midst. The brasses are regularly perforated in four rows. The reed is oblique, and close above the warp-beam loosely fastened, (see Figs. 284 and 351,) that it (if required) may be lifted a little, and not slip down. The warp-threads are marked with f. Fig. 350 gives the view of a brass; Fig. 350 a transverse section of a row of eyes; and Fig. 351.

The fourfold divided warp passes vertically upwards between two parallel guide-bars, and unites close above them into two series of warp-threads, two and two series of the warp being drawn into two series of guides. The guide-bars (see Figs. 284, 286, 330, 331, 332, 333, 334, 335, 336, 337) are placed along the whole machine and supported at both ends and in the centre, that they may retain their parallel situation and their relative position. They are in all figures marked with a and b—a marking the front and b the back guide-bar. Both guide-bars are liable to lateral movement, by which a lateral shifting of the warp is effected. The series of guides c and d consist, like the reed F, of single pieces put together lengthwise. The number of the pieces, which are to be of entirely equal breadth, depends upon the number of the warp-threads, or of the breadth of the texture.

Every single piece, consisting of a mixture of lead and zinc, is provided with an equal number of guides, being made of iron or steel wire, and cast together with the pieces in uniform distance from each other. Fig. 334 gives a front view of a single lead-piece in its position when screwed to the guide-bar; Fig. 335 a side view of it; Fig. 336 represents a single guide; and Fig. 337 an ear. Guides are almost exclusively used, as by them the drawing in of the warp-threads is considerably facilitated.

The two series of guides c and d divide the warp into two opposite equal parts, of which the texture is to be made. At the point where the texture begins both unite in one warp and are placed in one plane. Each half extends over the whole breadth of the texture, the threads of each series having double the distance between themselves, apparent in the texture.

This arrangement is of the greatest importance. The lace-weaving is facilitated by it, and at the same time some parts can be made stronger, which is of great avail regarding durability and quickness of operation. Moreover, the inconvenience of entangling and tearing the threads is removed.

The texture begins near M N, where the interlacing and twisting of the warp and weft threads is accomplished.

Fig. 360 shows the formation of the regular holes or meshes, completed by the round *points* of the *point-bars* M and N, after the intertwisting of the warp and weft threads having been accomplished

below. The formation of the meshes is effected round the points of the point-bars, and simultaneously across the whole breadth of the warp in horizontal lines. For the formation of one row of meshes only one point-bar is required. Both alternate in this operation, so that one point-bar holds the finished row of meshes, while the other takes up the next following, and thus they relieve each other continually.

In proportion to the proceeding of the formation of the rows of meshes, the texture is wound upon the lace-beam. Figs. 284, 285, 286, 287, 288, 289, 321, 322, 328, and 329, will illustrate what is said here.

The point-bars are marked with M and N,—the front bar with M, and the back point-bar with N. Both are provided with points which are adapted to each other.

The points are cast in lead-pieces which are fixed to the point-bars by screws, (see Figs. 321, 322 and 328, 329;) the last-mentioned figure shows a point-piece N separately. Every point-piece must have exactly the same breadth as the lead-pieces of the series of guides *c* and *d*, whose number is equal to that of the point-pieces. The number of points in each point-piece is likewise equal to that of the guides in each lead-piece. By Fig. 328, it will be perceived that between the single points there is room enough not only for the opposite points, but also for the intertwisting threads.

Z represents the *lace-beam*, running parallel with the warp-beam, and being of equal length, and of equal or smaller diameter. It turns on pivots, whose sockets are placed in similar manner to those of the warp-beam. See Fig. 286.

The successive turning of the lace-beam is effected by a regulator, moved by the machinery.

The finished lace passes on its way from the point-bars to the lace-beam across the rounded iron bar D, Figs. 284, 286, 352, 353, and 354, which serves to support the texture. At both ends of it are rowels r_3 (355) turning on small pivots. The pricks of these rowels enter the meshes close by the borders of the texture, thus preventing its running together. The larger rowels R_1, close above the smaller ones, are intended for the same purpose.

The lace is, by its winding upon the lace-beam, on account of its tension, somewhat less broad than it is when lying on the point-bars.

The union of the warp and weft takes place below M N, and is effected by two rows of weft-threads, each of which is wound round a small *bobbin*, that passes between two and two warp-threads. Thus there are two rows of bobbins which are moved round the warps; and in this way the intertwisting is effected. The bobbin-rows stand parallel with the breadth of the warp, and either both rows before or behind it; or one row before and one behind it.

That the bobbins may occupy these respective positions, they are pushed from one side to the other on *carriages* and *bolts*. Each bobbin has its separate carriage and bolt; and two and two bobbins are with their carriages behind each other, on one bolt. The whole series of bolts is called a *comb*.

The bobbins, carriages, and bolts, are of a peculiar shape, as may be seen by Figs. 284, 286, 288, 289 ·96, 297, 298, 306, 307, 308, 326, 338, 339.

Fig. 296, gives the side view of a carriage with inserted bobbin.

Fig. 297, section of a bobbin.

Fig. 298, carriage viewed from the other side, and without the bobbin.

Fig. 299, section.

Figs. 306, 307_a, and 308_b, show a bolt.

Fig. 306, gives a side view of the bolt, when placed in the machine.

Fig. 307_a, represents its lower edge turned towards the warp.

Fig. 308_b, gives a section of the bolt at its opposite end.

The single bolts are, like the points and guides, cast in lead-pieces, each of which contains as many bolts as there are points and guides in one lead-piece. The breadth of the comb-pieces is exactly equal to that of the other lead-pieces.

Figs. 338, (view from behind,) 339, (front view,) and 326, (side view,) represent a comb-piece.

The small interstices between the single bolts receive the carriages, which thus, with their grooves, are placed upon the bolts. See Figs. 298, 299, 306, 326, 338, and 339.

The bolt-pieces are by the side of each other screwed on a bar, and thus form together the comb.

One of such combs is placed before, and one behind the warp, and the distance between both is not greater than required for the easy passage of the double row of warp-threads.

The bolts of both combs are exactly opposite each other, that the carriages may be pushed from one comb to the other without obstruction.

The bolts are circular, to keep the bobbin-threads at an equal tension, while the carriages are pushed to and fro.

The width of the carriages, compared with the inconsiderable distance by which their bolts stand off, on both sides of the warp, permits this pushing from one comb to the other without any difficulty. Both combs have their correct mutual position with reference to the centre of the circular line.

In the figures, the front comb is marked with L, and the back comb with L_1; the bars on which the combs are screwed, and which are called bolt-bars, are marked with K and K_1, and the carriage-lines with l and l_1. The carriage-line l, which is always nearest to the operative, is called the front, and l_1 the back line. For this reason they use to say front and back carriage-thread series, or briefly front and back carriage-threads, instead of bobbin-thread series, etc.

The unwinding of the threads and turning motion of the bobbins, is to be seen by Figs. 296, 297, 298, and 299.

The swinging movement of the carriages on their circular bolts is not a continual one, but is made in short regular intervals. The pauses occur as soon as the carriage-lines, coming from the one or the other side, have passed the warp-threads and stand completely on their bolts. Meanwhile the shifting of the warp-threads (not being hindered now by the carriages) to the right or to the left takes place. As soon as the carriages pass the warp-threads, the regular twisting and crossing is accomplished, and at the same time the mesh of net completed.

The swinging movement of the carriages is effected in the following manner. See Figs. 284, 288, and 289.

E and E_1 are two bars, parallel to the carriage-lines, but somewhat longer, and their oblique side turned towards them.

Both bars are, with their ends, placed so that they cannot shift their places. Figs. 284, 288, and 289 show the different positions which they occupy. They are close above the comb, seize the carriages, and push them from one comb to the other, as soon as put in a swinging motion.

This motion is in consequence of their moveable sockets being put in the rifts of the cradle-pieces I_1, which are moved backwards and forwards like a pendulum. See Figs. 284, 285, 286, 287, 340 to 344.

By Figs. 284 and 289, it may be seen that these *pusher-bars* never can pass the centre, but stop at some distance from the warp before they make their retrograde motion. Thus the pushing of the carriages beyond the midst, cannot be effected by them; this must be done by the drawer-bars, or the blades of the locker, (here called *double-locker.*) These are marked with q, and the locker-bar on which they are screwed, with p. Fig. 294 gives a transverse section of the double locker-blades. The locker-bars p are placed at both sides of the warps below the comb, towards the bolts of the carriages. The locker-blades may be cast either each separately, or, more properly, both together, and then fastened to the locker-bar by screws. Their material is brass, but the bars are made of wrought-iron. The length of the combined locker-blades is somewhat exceeding that of the comb, and they therefore can seize a whole carriage-line at the pointed ends of the carriages projecting from beneath the comb. See Figs. 284, 288, 289, 296, and 298. By a slight angular movement of the blades, the carriages, pushed to them by the pusher-bars, are seized at their feet, and drawn across the midst of the machine through the warp-threads. The movements of the pusher-bars and lockers are thus supporting each other, and by this, the swinging of the carriages is completely effected. The lockers serve at the same time to keep back the carriage-lines during the above-mentioned pauses, thus prevent them getting into the centre, and bringing the warp-threads out of order during their shifting. The periodic angular movement of the locker is effected by motive power, dented bars and eccentric disks acting upon the axis of the locker-bars. Figs. 284, 288, and 289 will more distinctly explain the operations of the single locker-blades.

In Fig. 284, both carriage-lines stand on the back comb. The front blade of the back locker holds the hind-feet of the front carriage-line, and thus retains also the back carriage line. The front locker is completely turned over, so that its blades by no means hinder the carriages from sliding on the front comb. In Fig. 285, the front blade of the front locker has already drawn over the front carriage-line, and keeps it on the comb. The back carriage-line is on the back comb, and is retained there by a blade of the back locker.

In Fig. 286, both carriage-lines are on the front comb, and the back line, together with the front carriage-line, is retained by the back locker-blade. The figures also show the counter-movement of both lockers, the necessity of the removal and height of the locker-blades, etc. This highly ingenious contrivance is invented by Mr. Morley.

The chief parts of the machine, their movements and functions in general, are now known, and it will hereafter not be difficult more to follow the movements, operations, and connection. But first, a stand-point must be afforded, from which the whole progress of the machine can be overlooked. For this purpose, it will be suitable to commence with the moment when a row of meshes is completed and seized by the point-bars, and at the same time to notice the particulars concerning the rotation of the shafts, wheels, and disks.

The great dented wheel V (with 48 cogs) at the principal axis W, makes *three* rotations during the two movement-periods, in which two rows of meshes are completed. It is the same with the two dented wheels s_1 and s_2.

The large heart-shaped disk U, and the two small locker-disks v_1 and v_2 make likewise *three* rotations in this time. Each rotation of these disks brings about four interrupted movements of the pushing and locker bars. Every such movement causes a carriage-line to cross a comb. Consequently, for completing one row of meshes, six movements of carriage-lines are required.

The dented wheels t_1 and t_2, (of the axis t,) which are turned by s_1 and s_2, have thrice as many cogs as the latter dented wheels, and, for this reason, they make only one rotation, while the principal axis W makes three. It is the same with the shafts t, and the pushing-wheels and lifting-thumbs connected with them.

The notches and elevations of the pushing or notched wheels, occupy nearly one-twelfth of the periphery, if taken together.

In Figs. 345, 346, 347, and 348, their mutual position with reference to their notches and elevations is shown, as they must be put on the shafts. This position corresponds to the moment which is represented in the figure of the machines, in Figs. 284, 285, 286, and 287. The disks move in the direction of the arrows.

The pushing-points of the levers are in a vertical plane going through the axis of the shafts t. Equally marked points of the periphery of the pushing or ratchet wheels are during the movement entering this vertical plane, and acting upon their levers simultaneously.

The ratchet wheels in Figs. 345 and 346, are, during a total rotation of the axis, (or during the completion of two rows of meshes,) pushing the front comb twice to the right and twice to the left; the notched wheel o_1, Fig. 347, pushes in the same time the front guide-bar, and with it the front half of the warp, thrice to the right and to the left, and the notched wheel o_2, Fig. 348, does the same with the back guide-bar and the back half of the warp.

The shell-wheel R_2 of the front point-bar (represented in Fig. 287, but omitted in Figs. 288 and 289) has a position entirely opposed to that of R_3, so that the indenture of the shell-wheel R_2 stands deepest while that of R_3 stands highest. (See Fig. 289.)

The points 9, 10, and 11, of the lifting-thumb Q_1, (see Figs. 288 and 289,) are, with reference to the

simultaneous pushing of the ratchet-wheels, corresponding about the points 20, 22, and 12; that is to say, as soon as the points 9, 10, and 11 are active, the points 20, 22, and 12 follow this movement in succession. On the other hand, the edge of the indenture in the shell-wheel R_2 corresponds respectively with 10 and about 16, its centre with 11 and 18, and its opposite edge with 19. The corresponding points of R_3 are respectively 10, and about 22, then 11, 12, and 13.

The relative position of all parts being thus correctly stated, we shall follow the various movements from the moment when a row of meshes has just been completed, and the points are falling or catching in the meshes.

Fig. 289 shows the positions of most of the chief parts in this movement; and there we see that follows:—

The back point-bar is about to fall off. Both carriage-lines are on the front comb. The front half of the warp assumes its usual position, (that is to say, its most frequent position.) Point 12 on o_1 is under the point of the lever x_1, (see Fig. 286.)

The back half of the warp has just now shifted from the left to the right, the lever x_2 being fallen off from 12 on o_2.

The movement ensues. The back point-bar N lifts the row of meshes. The back carriage-line l_1 goes up to the back comb.

After the shafts t and W have made respectively one-twelfth and a quarter of rotation, a pause ensues.

The point-bars have lifted up their rows of meshes almost entirely.

The back carriage-line is on the back comb. All carriages have made a comb-movement.

The front half of the warp retains its usual position, (see above;) the point 13 on o_1 is advanced until beneath the point of the lever.

The back half of the warp has shifted from the right to the left, (the pushing-lever x_2 has risen above the prominence at 13 on o_2.) and assumes its usual position, (see above.)

The first movement is accomplished; and the different parts are in the position of Fig. 288.

The second movement begins. The point-bars are at rest.

The front carriage-line goes up to the back comb, where the back carriage-line moves higher up.

The shafts t and W make, respectively, one-twelfth and a quarter of rotation, and a pause ensues.

Both carriage-lines are on the back comb.

The front comb is pushed from the right to the left, the points 14 of o and o_3, being advanced to beneath the points of the levers.

The front half of the warp has shifted from the right to the left.

The back half of the warp retains its usual position.

The point-bars are at rest.

The second movement is accomplished.

The positions of the different parts represented in the figures, (with the exception of Figs. 288 and 89,) are corresponding to this moment.

The third movement begins.

The front carriage-line l returns to the front comb.

The front point-bar begins to leave its row of meshes. This curve from 9 to 10 of the lifting-thumb acts upon the pin of the fork.

The shafts t make again one-twelfth of their rotation, and the pause ensues.

The front carriage-line is on the front comb, and has moved from the left to the right. The back carriage-line is on the back comb.

The front half of the warp has shifted from the left to the right, and is in its usual position, as is the back half also.

The front point-bar is lifted almost entirely out of the meshes.

The third movement is accomplished.

The fourth movement begins.

The back carriage-line goes up to the front comb.

The front point-bar is lifted out.

The shafts t make their fourth twelfth of the rotation, and the pause ensues.

Both carriage-lines are on the front comb, and move from the right to the left.

The front and back parts of the warp are in their usual position.

The front point-bar is about to lower.

The fourth movement is accomplished.

The fifth movement begins.

The back carriage-line returns to the back comb.

The point-bar lowers. The fifth twelfth of the rotation of the shafts t is made, and the pause ensues.

The back carriage-line is on the back comb.

The front carriage-line is on the front comb, and has moved from the left to the right.

The front half of the warp is in its usual position, and the back half has shifted from the left to the right.

The fifth movement is accomplished.

The sixth movement begins.

The front carriage-line goes up to the back comb.

The front point-bar is lowering, and six-twelfths or one-half of rotation of the shafts t ensues. Both carriage-lines are on the back comb. The interchange or traversing of the carriages is accomplished The carriages have advanced to the right by one station.

The front half of the warp is in its usual position.

The back half of the warp has shifted from the right to the left.

The front point-bar has lowered. It is now exactly in the same position as the back point-bar was in the beginning of the first movement, (see Fig. 289,) and is nearly about to fall off.

The sixth movement is accomplished, and therewith a row of meshes completed.

These six movements constitute the first period of operations.

The next, or second period, comprises almost the same movements, with the exception of the comb-shiftings, as will be perceived by the following explanation:—

The seventh movement begins.

The front carriage-line goes up to the front comb.

The front point-bar falls off, and lifts the seized row of meshes.

The shafts *t* make the seventh twelfth of their rotation.

The front carriage-line is on the front comb, and the back one on the back comb.

The front half of the warp has shifted from the right to the left; the back half is in its usual position.

The front point-bar is lifted almost entirely.

The seventh movement is accomplished.

The eighth movement begins.

The back carriage-line comes up to the front comb.

The front point-bar is lifted.

The shafts *t* make the eighth twelfth of their rotation.

Both carriages are on the front comb.

The front half of the warp having shifted from the left to the right, assumes its usual position.

The back half of the warp retains its usual position.

Both point-bars are at rest.

The eighth movement is accomplished.

The ninth movement begins.

The back carriage-line goes up to the back comb.

The back point-bar begins to leave the meshes, and nine-twelfths of rotation of the shafts *t* are made.

The back carriage-line is on the back comb, and the front line on the front comb.

The front half of the warp is in its usual position.

The back half of the warp shifts from the left to the right.

The back point-bar has nearly left the meshes.

The ninth movement is accomplished.

The tenth movement begins.

The front carriage-line goes up to the back comb.

The back point-bar is entirely taken out.

The tenth twelfth of rotation of the shafts *t* ensues.

Both carriage-lines are on the back comb.

The front half of the warp shifts from the right to the left, and the back half shifts from the left to the right.

The back point-bar is about to lower.

The tenth movement is accomplished.

The eleventh movement begins.

The front carriage-line returns to the front comb.

The back point-bar lowers, and the eleventh twelfth of rotation of the shafts *t* ensues.

The front carriage-line is on the front comb, and the back line on the back comb.

The front half of the warp shifts from the left to the right, and the back half retains its usual position.

The back point-bar is near its deepest standing.

The eleventh movement is accomplished.

The twelfth movement begins.

The back carriage-line goes up to the front comb.

The back point-bar attains its deepest standing. The last twelfth or a total rotation of the shafts *t* is accomplished.

Both carriage-lines are on the front comb.

The front half of the warp is in its usual position, and the back half shifts from the left to the right.

The back point-bar is in its deepest standing, and about to fall off.

The twelfth movement is accomplished. A fresh row of meshes is completed, and is forthwith taken up by the back point-bar.

With the twelfth movement the second period of operations is accomplished, and all is in the position of Fig. 289. Hereupon the same circulation of movements and functions of the different parts begins, and so on.

The following table will serve to render the just-described periods of movements still more conspicuous. The superscriptions of the columns will prove to be sufficient to explain the signification of the letters; and it may only be remarked, that A signifies the front carriage-line, and B the back carriage-line. Each column contains two lines, filled either with points or letters, thus indicating the mutual position of the concerning threads and carriages after every lateral movement. The asterisks (*) in the column superscribed "Front comb," serve to direct the attention on the shifting of the comb.

TABLE *of the Periods of Movements.*

First Period of Movements

Movements.	Front comb.	Front half of the warp.	Back half of the warp.	Back comb.	Movement of the point-bar.
End of the 12th or beginning of the 1st..................	• • A B	• *a*	• *b*	• • • •	The back point-bar is about to fall off.
End of the 1st or beginning of the 2d..................	• • • A	• *a*	*b* •	• • B •	The back point-bar has taken up the row of meshes.
End of the 2d or beginning of the 3d..................	* * • •	*a* •	*b* •	• • A B	Both point-bars at rest.
End of the 3d or beginning of the 4th..................	• • * *A	• *a*	*b* •	• • B •	The front point-bar is lifted out of the meshes.
End of the 4th or beginning of the 5th..................	*A *B • •	• *a*	*b* •	• • • •	The front point-bar is about to lower.
End of the 5th or beginning of the 6th..................	• • * *A	• *a*	• *b*	• • B •	The front point-bar is lowering deeper.
End of the 6th or beginning of the 7th..................	• • • •	• *a*	*b* •	• • A B	The front point-bar has lowered deepest and is about to fall off.
Second Period of Movements.					
End of the 7th or beginning of the 8th..................	• • • A	*a* •	*b* •	• • B •	The front point-bar has lifted the row of meshes.
End of the 8th or beginning of the 9th..................	• • A B	• *a*	*b* •	• • • •	Both point-bars at rest.
End of the 9th or beginning of the 10th..................	• • • A	• *a*	• *b*	• • B •	The back point-bar is lifted out of the meshes.
End of the 10th or beginning of the 11th..................	• • • •	*a* •	*b* •	• • A B	The back point-bar is about to lower.
End of the 11th or beginning of the 12th..................	• • • A	• *a*	*b* •	• • B •	The back point-bar lowers deeper.
End of the 12th or beginning of the 1st..................	• • A B	• *a*	• *b*	• • • •	The back point-bar is about to fall off.

A comparison of this detailed statement, with the illustration given in Fig. 360, will afford a still clearer view of the intertwisting and crossing of the warp and weft or carriage-threads.

In Fig. 360 the warp-threads are marked with *f*. They proceed downwards in serpentine lines, and receive their contorsion from the tension of the weft-threads twisted obliquely round them alternately to the right and the left hand. Before this union, and beneath the point-bars, the warp-threads are tentered vertically. So that the front half of the warp may be better distinguished from the back half, the threads of the former are hatched.

The front carriage-threads are marked with k, and the back threads with k_1. The figure shows the texture on a very large scale. The web consists of nine warp and nine weft threads. Five threads belong to the back half of the warp, and four threads to the front half.

Each (horizontally directed) row of meshes contains four holes or meshes.

The hatched circles within the meshes represent the points of the two point-bars, and are marked with M and N.

Description of an eight-quarters stripe machine.—Machines of this kind furnish bobbinet stripes or quillings, forming one broad piece during the fabrication, but which afterwards are separated from each other.

As these quillings or edgings, for the sake of beauty and solidity, must be, as it were, without a seam, this manufacturing requires a particular contrivance in the bobbinet machines.

The above-described double-locker machine may easily be arranged for manufacturing quillings; and the most practical and suitable contrivances for this purpose are those invented by Mr. Croft.

In Fig. 369 are represented two stripes of equal breadth, and united in such manner as they appear in the whole piece on the lace-beam. The borders or selvages are hatched and marked with f_3 and f_4.

The connecting thread, running in zigzag from one mesh to the other, is marked with k_3, and the other warp and carriage threads respectively with f and kk_1.

Each stripe being a plain narrow lace in itself, and the carriage-threads proceeding in their slanting directions, separately in the one and in the other, of course a contrivance is required in order that the carriages may turn back at the two inner selvages as well as at the two outer ones. This and all other required arrangements are illustrated by Figs. 361 to 394.

Fig. 378 represents a double-locker stripe machine in transverse section, in which latter Figs. 385, 386, 387, 388, and 389, are also given. The most essential parts of the machine are to be seen in Fig. 378.

Beginning from below, there will be perceived two warp-beams, G and G_3. Round the larger one is wound the warp for the plain texture, and round the other are twisted the commonly somewhat stronger selvages f_3 and f_4. In case the latter should be of equal thickness as the other warp-threads, one beam would be sufficient.

The warp-threads are to be drawn through the kind of reed F, and thence through the series of guides c and d, which are fastened to the guide-bars a and b.

The selvage-threads are only laid over the wooden framing-staves of the reed F, (see Fig. 378,) and then (on account of their peculiar lateral movement) drawn through particular iron or brass ears, (one of which is represented by Figs. 391 and 392,) called selvage-guides, which are fastened to the guide-bars a_3 and b_4. The selvage guide-bars are provided with similar sockets, supports, adjusting screws, levers, and springs, as a and b.

The warp is not divided into two equal parts as in the machine described above, but is drawn through the front and back guides c and d unequally divided, and this in such a manner, that in the front warp-half one, and in back half two, warp-threads are omitted at every border of the stripe. The corresponding guides, in the series of guides, are broken off as superfluous.

The selvage-threads, on the other hand, are equally divided, drawn through the series of guides c_4 and d_3, yet those marked with f_3 (see Fig. 369) exclusively through the front, and those marked with f_4 through the back series.

Between the combs L and L_1 all warp and selvage threads are drawn up in two rows, and led to the points n of the point-bars M and N, beneath which the texture is formed, after which it proceeds to the lace-beam.

The comb and the lockers, and locker-bars p and q, are set up in the usual manner.

The carriages are likewise put in with two lines, odd carriage, etc., as has been described above. Yet in the back line, right opposite to the selvage-threads, there are also the turn-again and whipping carriages, briefly called *whipper-carriages*, with the thick and strong connecting threads k_3, (see Fig. 309.) The whipper-carriages make upon the whole the same movements as the other carriages, with the only difference that they do not shift their places, but are running to and fro in the same bolts. During the shifting, they remain in the back comb, while the other carriages change their places in each stripe-section.

Before their peculiar movement, (illustrated by the figures from 378 to 382,) during the shifting, can be explained, some parts and contrivances connected with it must be viewed.

Close beneath the locker-bars p are parallel with them the so-called *picker-bars*, to which the *pickers* p_3 are fastened by screws. The picker-bars have exactly such sockets and supports as the locker-bars At the one end is fixed a short arm e_1, moved by the drawer-bar e^2, by which the picker-bar, with the pickers, can be put in a slight angular movement.

The pickers, made of stiff hammered iron or brass, Figs. 392 and 393, are performing here the functions of the locker blades in the above-described machine, as they, like them, seize the heels or catches of the carriages and push the latter onward, or respectively set them in their places. They, moreover, serve to regulate the movements of the whipper-carriages, and are to be advanced as far as possible towards the midst, yet in such manner that they may not impede the series of guides in their lateral movements.

To retain the whipper-carriages on the back bolt-bar, the back pusher-bar E_1 must be placed by a particular contrivance, which is illustrated by Figs. 378 and 381, and especially by Figs. 385 and 389.

The pusher-bar E_1, made of strong iron or spring steel plates, is at its long outsides strengthened by a rib of wrought-iron and provided with a pivot, by means of which the bar is placed in the sockets of the cradle-pieces I_1 in Figs. 284, 285, 286, etc. The bar has narrow but deep notches, intended to receive the whipper-carriages while the other carriages are shifting their places; but as soon as this shifting is accomplished, the whipper-carriages are let out, and the notches are closed by the covers d_4, which are fixed to the guide-bar g_3, and represented in Figs. 388 and 389. The covers are made of thin iron plate. The guide-bar g_3 is, by means of iron pieces e_3, fixed to the above-mentioned rib in such manner that it is easily to be moved sidewise, and keeps the covers close upon the notches. The bar is constantly attracted or drawn by a small but sufficiently strong spiral spring, fixed with its end to the pusher-bar E_1. The iron pieces e_3, and the slits of the guide-bar g_3, are squared thus, that the covers are exactly upon the notches as long as the spring is acting. Fig. 385 represents this movement.

The uncovering of the notches is effected by a lateral movement of the guide-bar g_3 to the right, and this movement is brought on by the action of a lever on the pivot or tenon a_4 at the bar.

Figs. 390 (giving a side view) and 391 (horizontal section close above the comb) serve to illustrate this movement. K is the front bolt, which, in the moment of the shifting, moves from the right to the left with the comb L. At its lower edge is applied the trigger h_3 which grasps the short one of the two arms of the lever F_3. The turning takes place on the pivot s_3 fixed at a suitable place in the frame. The long lever-arm, bent exactly in conformity with the curve of the comb, and placed in such manner that it is tight beneath the bar E_1, lies close to the left side of the tenon a_4.

Thus as soon as the bolt-bar K is moving to the left, the long arm of the lever F_3, moving to the right, presses against the tenon a_4, overcomes the power of the spiral spring, pushes the guide-bar g_3 to the right, and opens the notches of the pusher-bar.

The notches must be kept open until the shifting is accomplished. But the bolt-bar turning again from the left to the right, after the first quarter of the shifting movement, and, consequently, the long arm of the lever F_3 making the inverse movement, the covers would close the notches again and bring about confusion, if there had not been made a contrivance for preventing it. The chief instrument of this contrivance is the parrying-ledge h_4, screwed on the back bolt-bar. Its position relative to the lever F_3 and the tenon a_4 is shown by the Figs. 390 and 391. The tenon a_4 leans against the parrying-ledge as soon as it is pressed by the lever F_3, and does not give way until the shifting is accomplished. The positions of the tenon a_4, marked with dotted points in Figs. 390 and 391, will sufficiently illustrate this statement.

We shall now take a view of the peculiar movements of the whipper-carriages in the moment of the shifting.

Fig. 378 represents the concurring parts in the movement when the shifting of the front comb begins. Both carriage-lines are on the back comb.

In the next movement the comb makes its lateral movement; the lever F_3 acts upon a_4, and the notches of the pusher-bar E_1 are opened. Simultaneously the back pickers are, by the angular movement of the picker-bars, moved upwards. They now seize the shifted carriages at their heels or catches and push them onward, see Fig. 379, while the other carriages remain at their places, and the whipper-carriages (marked with k_3) pass into the notches of the pusher-bar E_1.

Now the movement of the pusher-bar and locker begins; E_1 pushing onward those carriages, which are not retained by the pickers, and the back locker lowering. As soon as the outer locker-blade is within the back heels of the retained carriages, the pickers move downwards, the just-mentioned carriages are seized by the outer blade of the back locker, and the carriage-movement ensues in the usual manner. The front locker draws the carriages, pushed to it by the pusher-bar E_1, up to the front comb, where, opposite to each whipper-carriage, one common carriage is lacking, (which may appear a matter of course by the above given statement,) and is instead of this in the back line of it. The back carriage-line on the back comb is complete, and has behind itself the line of the whipper-carriages which had been retained in the notches of the pusher-bar E_1. (See Fig. 380.)

The comb moves back; the carriage-movement ensues; the back pusher-bar causes all carriages, without any exception, to move onward; the back locker falls off and the front locker seizes the carriages presented to it and draws them up to the front comb. But just before the front locker seizes the heels of the carriages, the back pickers move upwards again, and consequently retain the whipper-carriages on the back comb. Meanwhile the other carriages have been drawn up to the front comb, where now two lines are, of which the inner one is complete, while in the outer one as many carriages are lacking as there are whipper-carriages on the opposite side. The position of the concurring parts in this movement is represented by Fig. 381.

The back pickers are thus, in this period of movements, performing the function of the back locker, which (as is shown by Fig. 381) has completely turned round, and cannot, for this reason, retain the whipper-carriages.

As soon as now the front comb has moved again from the right to the left, the front pickers spring up, and, seizing the (not in pairs) standing carriages on the front comb at their heels, press them upwards until their back heels or catches are beyond the outer blade of the front locker. (See Fig. 382.) The back pickers remain in their position represented by Fig. 381. Then the usual carriage-movement begins, and before the front comb moves from the left to the right, the front as well as the back pickers fall off. The comb-shifting ensues, and now both carriage-lines on the front and on the back comb are complete. The interchange or traversing of the carriages throughout the whole width of each texture-stripe has occurred, and the movement of the carriages of the complete lines continues in the usual manner until the shifting takes place anew.

This shifting, i. e., the interchange or traversing of the carriages in the texture-stripes, is indeed not easily to be understood; however, the following statement will prove adapted to render the matter pretty clear.

The common carriages are marked with *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *k*, and the whipper-carriages with k_3; their number is in conformity to the pattern in Fig. 369. The position of the carriages and combs is, according to Fig. 378, the following:

First Position after the first shifting of the front comb. — *Commencement.*	. a b c d k_3 a b c d k_3	back comb.
	. k h g f e k h g f e	
	. . . .	
	. . . .	
	. . . .	
	• • • • • • • • • •	
	• • • • • • • • • • . . .	front comb.

The big points represent the concurring places for the carriages. As soon as the carriages are on the front comb, their position is the following:

First Position. — *End.*	. • • • • k_3 • • • • k_3 . .	back comb.
	a b c d e a b c d e	
	. . . .	
	. . . .	
	. . . .	
	• k h g f • k h g f . .	front comb.
	• • • • • • • • • •	

After the comb's lateral movement to the right, the carriages stand thus:

		·	·	·	·	k_3	·	·	·	·	k_3	. . .	back comb.
		a	b	c	d	e	a	b	c	d	e	. . .	
Second Position.		.	.	.	.	.	.	.	.	.	.		
—		.	.	.	.	.	.	.	.	.	.		
Beginning.		.	.	.	.	.	.	.	.	.	.		
		·	k	h	g	f	·	k	h	g	f	. . .	front comb.
		·	·	·	·	·	·	·	·	·	·		

This position corresponds to Fig. 380; yet as soon as the back carriage-lines have passed the front comb, the position is the following:

		·	·	·	·	·	·	·	·	·	·	.	back comb.
		·	·	·	·	k_3	·	·	·	·	k_3	. .	
Second Position.		.	.	.	.	.	.	.	.	.	.		
—		.	.	.	.	.	.	.	.	.	.		
End.		.	.	.	.	.	.	.	.	.	.		
		a	b	c	d	e	a	b	c	d	e		
		·	k	h	g	f	·	k	h	g	f	. . .	front comb.

The comb moves to the left, and now the carriages stand thus:

		·	·	·	·	·	·	·	·	·	·	. . . .	back comb.
		·	·	·	·	k_3	·	·	·	·	k_3	. . .	
Third Position.		.	.	.	.	.	.	.	.	.	.		
—		.	.	.	.	.	.	.	.	.	.		
Beginning.		.	.	.	.	.	.	.	.	.	.		
	a	b	c	d	e	a	b	c	d	e			
	·	k	h	g	f	·	k	h	g	f		. . .	front comb.

This position corresponds to Fig. 381. The carriages move up to the back comb, and their position is now the following:

		·	·	·	·	·	·	·	·	·	·	. . .	back comb
		b	c	d	e	k_3	b	c	d	e	k_3	. . .	
Third Position.		.	.	.	.	.	.	.	.	.	.		
—		.	.	.	.	.	.	.	.	.	.		
End.		.	.	.	.	.	.	.	.	.	.		
	a	k	h	g	f	a	k	h	g	f		. . .	front comb.
	·	·	·	·	·	·	·	·	·	·			

The comb moves back, and the shifting of the carriages is now accomplished; for the position is thus:

	·	·	·	·	·	·	·	·	·	·	. . .	back comb.
	b	c	d	e	k_3	b	c	d	e	k_3	. . .	
	.	.	.	.	.	.	.	.	.	.		
Fourth Position.	.	.	.	.	.	.	.	.	.	.		
	.	.	.	.	.	.	.	.	.	.		
	a	k	h	g	f	a	k	h	g	f	. . .	front comb.
	·	·	·	·	·	·	·	·	·	·		

&c., &c., &c.

This statement shows at the same time clearly, that all carriages, as for instance, *e* in the first position, or as after the shifting *f* in the fourth position, which are with the whipper-carriages in one and the same bolt, are doing the business of whipper-carriages.

At the ends of the carriage-lines no whipper-carriages nor pickers are required, because the hold-fast contrivance, applied here, together with the notches of the lockers, supply the action of the pickers.

The above explained interchange or traversing of the carriages is rendered necessary by the mentioned order of the warp-threads, and that the stripes of the texture may be provided with seams.

In manufacturing plain broad pieces, the front half of the warp containing one thread less than the back half, there must be in a pattern like that of Fig. 369, four front and five back warp-threads in each stripe. Further, the borders or selvages of plain broad pieces being made of the end threads of the back warp-threads, consequently the seam-threads of the stripes must likewise be contained in the back half of the warp. But as here, on account of the connecting thread, (running in zigzag,) the left seam-thread of a stripe must alternately pass over two bolts, these threads are to be drawn through particular guides adapted for this movement.

The lateral movements of the guide-bars are in the usual manner prepared by ratchet-wheels, levers and angular pieces, or swing-bars. But for effecting the just-mentioned movement for the particular guiding of the seam-threads, the stripe-machine must be provided with two ratchet-wheels more, which are fastened at the axis t, to the right of the machine. Besides these, there are required two other ratchet-wheels for the movement of the pickers, which are fastened at the same axis within the dented wheels t_1 and t_2. (See Fig. 286.) Sometimes the last-named wheels are arranged for this purpose in the manner illustrated by s_4 in Fig. 390.

The figures from 370 to 377 represent all ratchet-wheels of the double-locker stripe-machine. The directions of the arrows indicate those of the movements. The various acting points in the twelve different movements of the concurring parts are marked with ciphers. Equal marked points are simultaneously acting. Point 1 corresponds to the acting point indicated by Fig. 378.

Fig. 370 represents the right ratchet-wheel for the lateral movement of the comb; Fig. 371 the left one of this description; Fig. 372 the front ratchet-wheel for the warp-threads, and Fig. 374 the back ratchet-wheel for the same purpose. (These four wheels, already known by the description and illustrations of the broad plain bobbinet machine, are delineated here once more, in order to facilitate the view of the whole.) Fig. 373 represents the front ratchet-wheel for the seam-threads; Fig. 375 the back ratchet-wheel for the same purpose; Fig. 376 the back ratchet-wheel for the pickers, and Fig. 377 the front one of this description.

Following in the order of numbers the indentments of the ratchet-wheels, it becomes apparent that during the twelve different movements of the two principal movement-periods, (in which two rows of meshes are completed,) the shiftings of the warp-threads occur simultaneously, and in a successive order. Still more perspicuous the simultaneous operations of the ratchet-wheels will appear by supposing their peripheries to be stretched out into a straight line, as has been done in the following sketch.

By the lateral shiftings of the warp-threads, and by the interchange or traversing of the carriages, the formation of the web is effected; and all the intertwistings and decussations of the threads follow each other in the same order, as has been sufficiently explained above. The connection of the seam-threads with the connecting thread k_3, (Fig. 369,) is not brought on by perhaps a lateral movement of the latter, but only by the lateral movements of the seam-threads. Thus the intertwisting of k_3 and f (in the midst of the figure) is effected by a single shifting of the latter towards the former thread, (explained by Fig. 373,) while the intertwisting of the left seam-thread f_4 is effected by its double-shifting (See Fig. 375.)

The positions of the warp-threads towards each other and towards the carriages in the two principal movement-periods, are exposed in the following statement. In this $a, b, c, d, e, f, g, h, k$ signify the common carriages, k_3 the whipper-carriages; the asterisks (✱) signify the back seam-threads; the simple crosses (+) the front seam-threads; the large points (.) the common front and back warp-threads; and the vertical dashes (|) the void places for the carriages. The statement corresponds to the texture of Fig. 369.

First Movement. Acting point 12.

a b c d k_3 a b c d k_3 } .... back comb.
. | | | | | | | | |
✱ . . . . ✱ . . . . . ✱ ...... back seam-threads.
. . . . back warp-threads.
. . . . front warp-threads.
. . . + ... + ... front seam-threads.
k h g f e k h g f e } .... front comb.
| | | | | | | | | |

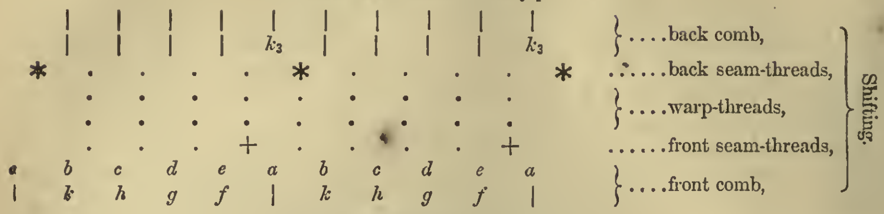
Second Movement. Acting point 1. (Position as in Fig. 378.)

a b c d k_3 a b c d k_3 } .... back comb,
k h g f e k h g f e
✱ . . . . ✱ . . . . . ✱ ...... back seam-threads, Shifting.
. . . . } .... warp-threads,
. . . .
. . . + ... + ... front seam-threads,
| | | | | | | | | } .... front comb,
| | | | | | | | |

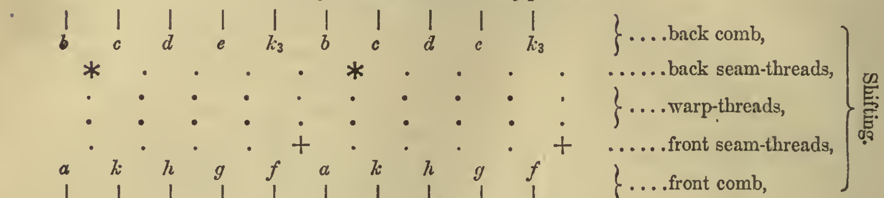
Third Movement. Acting point 2.

| | | | k_3 | | | | k_3 } .... back comb,
a b c d e a b c d e
✱ . . . ✱ . . . . . ✱ ...... back seam-threads, Shifting.
. . . . } .... warp-threads,
. . . .
. . . + ... + ... front seam-threads,
| k h g f | k h g f } .... front comb,
| | | | | | | | | |

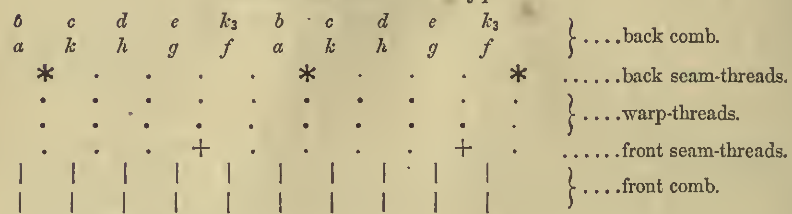
Fourth Movement. Acting point 3



Fifth Movement. Acting point 4.



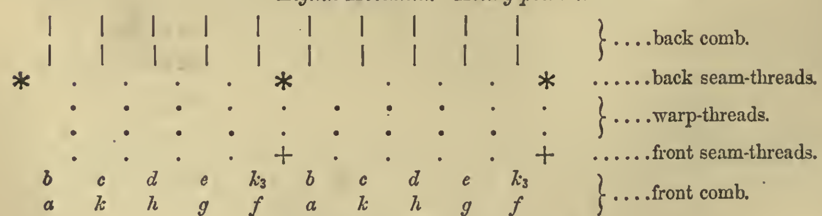
Sixth Movement. Acting point 5.



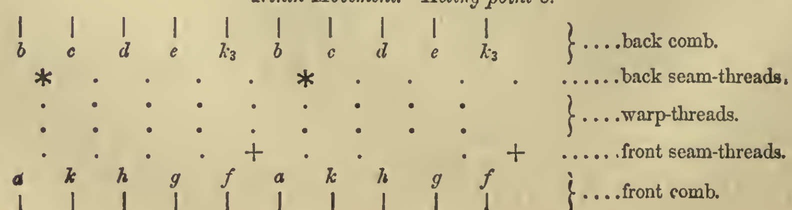
Now the first principal movement-period is finished, and one row of meshes is completed. The point-bars take up the completed row.

Seventh Movement. Acting point 6.

Eighth Movement. Acting point 7.



Ninth Movement. Acting point 8.



Tenth Movement. Acting point 9.

```
   b   c   d   e   k3  b   c   d   e   k3   } ....back comb.
   a   k   h   g   f   a   k   h   g   f    }
*          .   .   .   *   .   .       .   *   ......back seam-threads.
.      .   .   /.  .   .   .   .   .   .    } ....warp-threads.
.      .   .   .   .   .   .   .   .   .    }
.      .   .   .   +   .       .   .   +       ......front seam-threads.
   |   |   |   |   |   |   |   |   |   |    } ....front comb.
   |   |   |   |   |   |   |   |   |   |    }
```

Eleventh Movement. Acting point 10.

```
   |   |   |   |   |   |   |   |   |   |    } ....back comb.
   b   c   d   e   k3  b   c   d   e   k3   }
*      .   .   .       *   .   .   .   .   *   ......back seam-threads.
       .   .   .   .   .   .   .   .   .   .    } ....warp-threads.
       .   .   .   .   .   .   .   .   .   .    }
       .   .   .   +           .   .   +   .   ......front seam-threads.
   a   k   h   g   f   a   k   h   g   f    } ....front comb.
   |   |   |   |   |   |   |   |   |   |    }
```

Twelfth Movement. Acting point 11.

```
   |   |   |   |   |   |   |   |   |   |    } ....back comb.
   |   |   |   |   |   |   |   |   |   |    }
       *   .   .   .   .   *   .   .   .       * ......back seam-threads.
       .   .   .   .   .   .   .   .   .   .    } ....warp-threads.
       .   .   .   .   .   .   .   .   .   .    }
       .       .   +   .   .   .   .   +   .   ......front seam-threads.
   b   c   d   e   k3  b   c   d   e   k3   } ....back comb.
   a   k   h   g   f   a   k   h   g   f    }
```

Now the second principal movement-period has finished, a fresh row of meshes is completed, and forth with taken up by the back point-bar, and in this manner the cycle of movements is continuing.

The points of the point-bars take up the completed meshes in the usual manner, only two points in the midst are somewhat bent sidewise to give room for the connecting thread. (See Fig. 394.)

The breadth of the stripes is commonly fixed in conformity with numbers which coincide with the number of meshes running diagonally. Thus, for instance, the stripes in Fig. 369 would be marked with No. 8.

Figured bobbinet (or design bobbinet) is manufactured in three different ways:—

The common plain bobbinet is interwoven with embroidering or twisting threads. This interweaving can be done at single spots, as well as in continued lines. The first manner produces points or spots regulated by groups and figures of various descriptions; and the second manner produces ornamental stripes either in serpentine lines, or in zigzag, or otherwise arranged. The ornamental or embroidering threads consist usually of thick or colored yarn, in order that the pattern may have a better relief.

Machines for manufacturing bobbinet of this description, are: *Sneath's* improved single-locker machine; *Heathcoate's* patent machine; *Summer's* lever machine; *Sewell's* roller machine; *Draper's* machine, and *White's* improved machine.—The arrangements of these machines are very different, and it would lead us too far, to give any description whatever of them here. Heathcoate's machine is connected with a so-called *tatting machine*, by which the interweaving of ornamental threads is performed.

The simple intertwisting of threads in the plain bobbinet is altered in such manner, that at certain points of the web, larger holes or meshes are made, surrounded by common smaller ones. Some patterns of this description are called *grecian net*, the *honey-comb open work*, and the *roseau tull.*

The manufacturing of these webs requires, of course, more or less complicated arrangements in the machinery. Their chief peculiarity is, that the warp is to be divided in more than two parts, which have their lateral movements independent of each other. Frequently the movement of the carriages is in certain movement-periods somewhat altered too, similar to the case of the stripe-machine, which may indeed be considered as producing figured or design bobbinet, if the zigzag connection be regarded as a figure.

The arrangements of the first and second systems are combined, by which we obtain patterns with larger, and meshes with ornamental threads. Draper's machine is partly adapted to them. Upon the whole, the machinery is very complicated; and for this reason, almost everywhere the lever and single-locker systems are applied, because machines of this description can be more conveniently arranged and altered than double-locker machines.

BOILERS, for the generation of steam for engines, may be divided into three great classes. The and or stationary boiler, the locomotive boiler, and the marine boiler. In the first the combustion is

the least active, in the second excited by means of the exhaust or artificial draft. In the first the principles of combustion and proportion of parts are pretty accurately determined, but the circumstances under which the marine boiler is placed and the conditions it is required to fulfil are so different that as yet no one form, dimensions, or proportions can be said to be the standard.

Stationary Boilers. The *capacity* of steam-boilers should at least equal one cubic yard, or 27 cubic feet, for each horse-power, being a *minimum* space of 13·5 cubic feet for *steam*, and a *maximum* space of 13·5 cubic feet for *water*. In cylindrical boilers, plain, without any inside flue, and set upon the oven plan—that is, the flame and smoke passing direct from the bottom of the boiler to the chimney without any return flue—the maximum length in feet is 6 times the square root of the horse-power, or, if with a wheel draught, 4 times the square root of the horse-power. In cylindrical boilers with inside flue or flues passing through them, and with split draught, 3¼ times. If flued, and with inside uptake set with split draught, the length in feet should be from 3 to 3¼ times the square root of the horse-power; or, if with wheel draught, 3 times.

The *ash-pit* and entrance to it should be as large and free as possible. The area for entrance of air to ash-pit never less than ¼ the area of grate; 2 feet 6 inches is sufficiently deep for ash-pit.

The *fire-bars* inclining downwards 1 inch per foot, and cast as thin as possible consistent with necessary strength, not more than ¾ inch thick, and with ⅜ or ½ inch spaces between.

The *furnace* should have 3 cubic feet of space above each superficial foot of fire-bar surface.

Flues.—To determine the area of the flue and chimney, it must be considered that 150·35 cubic feet of air are required for the combustion of 1 lb. of coal. Of this air 44·64 feet combine with the gases evolved from the coal, and 105·71 feet with the solid portion of the coal. The combination of the air and gases increases their volume 1-10th. The 44·64 feet thus become 49·104 feet. The sum of 105·35 with the carbon remains the same. The total product of the combustion (without considering the increase of volume resulting from raising the temperature) of 1 lb. of coal, is therefore 105·71 + 49·104 = 154·814 cubic feet. Assuming the temperature of the furnace at 1000° Fahr., at which aëriform bodies are expanded to about three times their original bulk, the product will be 154·814 × 3 = 464·442 feet. Adopting the result of Dr. Ure's experiments, viz., that the products of combustion pass off at a velocity of 36 feet per second, the area to allow this quantity to pass off in an hour will be ·516 square inch. In a furnace in which 13 lbs. are burnt per hour on each square foot of grate, which is, according to Mr. Parkes, the average consumption throughout England, the minimum area over the bridge, or of the flue immediately behind the furnace, would be ·516 × 13 = 6·709 square inches. In practice, however, as a large surplus of air is always admitted, and the exactness supposed in this calculation cannot be secured, it is found advantageous to make the area 2 square inches instead of ·516. This gives 26 square inches of area over the bridge to every foot of grate where 13 lbs. of coal are consumed per hour to every foot of grate. As the temperature and bulk become gradually reduced in proportion to the distance from the fire, the area of the flue towards the chimney may be narrowed; but this should be done without awkward bends or sharp angles.

Proportion of heating or flue surface to size of grate.—In boilers burning 13 lbs. per foot per hour, 18 superficial feet of heating surface to each foot of grate is a good proportion. This proportion omits the *bottom* surface of flat flues, and from ⅓ to ¼ the surface in circular flues, as being inoperative.

Chimneys.—The area of the chimney should be ¾ that of the opening over the bridge, viz., 1½ inch per lb. of coal consumed, or 19½ inches for each foot of fire surface burning 13 lbs. per hour. But the whole diminution of flue should be made gradually, and not by any sudden contraction. A common rule is, that the minimum area of chimneys 24 to 30 yards high, is 4000 square inches for each 20 horse-power.

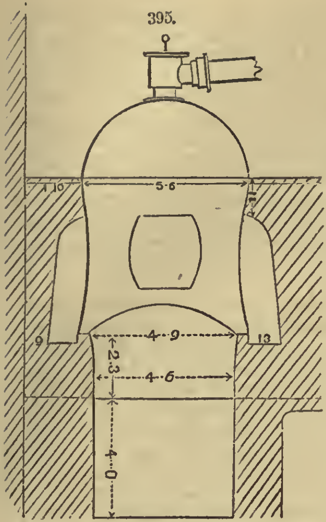
Furnaces and Boilers.—From a careful examination of some of the best constructed boilers and furnaces in Manchester, the ratio of grate-bar to absorbing surface was found to be 1 : 11·1, which, taken from fifteen boilers of the best construction, and worked with considerable skill, gives a fair average of the proportions of the furnace and the flue surface of each. On comparing the above with the boilers at work in Cornwall, it will be found that their relative proportions are as 1 to 25; and while 6 lbs. of good coal will evaporate in the Cornish boiler about 11½ lbs. of water, the utmost that the best wagon-shaped boiler has been known to accomplish is 8·7 lbs. of water to the lb. of coal. Hence the advantage of a small furnace and large flue surface, united, however, to abundance of boiler space, in order to attain a maximum effect by a slow and progressive rate of combustion.

Taking the amount of flue surface in a boiler exposed to the passing currents of heat as a criterion of its economic value, we shall then have according to computation a summary of comparison as follows;

Numbers.	Description of boiler.	Cubic contents in feet.	Area of heated surface in feet.	Ratio of the area of heating surface to cubic contents.
1	Old hemispherical boiler	420	128	1 : 3·28
2	Common wagon-boiler, without middle flue	1044	320	1 : 3·26
3	Wagon-boiler, with middle flue	894	432	1 : 2·06
4	Cylindrical boiler, without middle flue	789	225	1 : 3·50
5	Cylindrical boiler, with middle flue	579	360	1 : 1·65
6	Cylindrical boiler, with eight 10-inch iron tubes	605	567	1 : 1·06
7	Improved boiler, with two middle flues	575	548	1 : 1·01

* Armstrong on Steam-Boilers.

395.

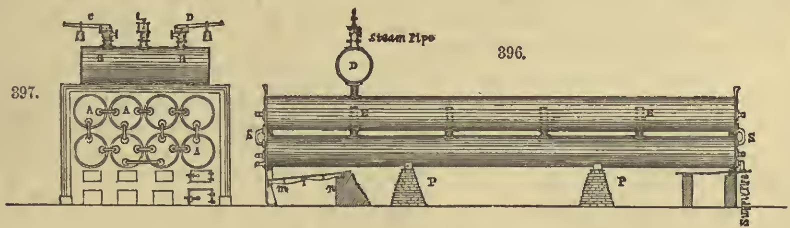


SCALE.—1-12th inch = 1 foot.
Transverse Section.

On the various forms of stationary boilers, Fig. 395, represents the *wagon* boiler, sometimes called the *caravan* or *oblong* boiler. This boiler succeeded the *haystack* boiler, but it is not adapted to resist the pressure of high steam; but up to 5 feet diameter, if provided with one or two or three longitudinal stays, of 1½ inch square from end to end, and cross stays at every two feet in the length, it may be safely worked up to 10 lbs. per square inch, and the evaporative results are economical. Their length is commonly from 16 to 24 feet. They are seldom used in this country.

Plain cylindrical boilers set in brick work, are in very common use for stationary engines, and especially at such places as it is inconvenient to get workmen to make repairs. They are usually from 30 to 40 inches in diameter, and from 30 to 40 feet long. The grate is placed at one end, being of about the width of the boiler and from 3 to 5 feet long. The chimney is at the opposite end. At the end of the grate is placed a bridge, as it is termed, which forms a back for the grate, and being brought within a few inches of the boiler, brings the flame in contact with its under surface.

Cylindrical boilers are often set in connection with each other, side by side. When set in rows, one above the other, or in *nests*, as they are called, the upper row being directly above the lower one, as in figs. 396,397, or better over the spaces, (there being one less boiler in the upper than in the lower row,) the evaporative effects, as instanced below, are excellent.



These boilers, which have now been in use by the Lowell Manufacturing Company at Lowell for two years, were constructed, from directions by Dr. A. A. Hayes, of Boston, by Messrs. Bancroft, Nightingale & Co., of Providence. One row of four boilers are set perpendicularly above another row of the same number, the fires being under the lower tier. The boilers are plain cylinders, 40 feet long and 33 inches diameter, having a surface exposed to the fires of 2,000 square feet, and containing about 1,200 cubic feet of water. The grates are in two heights of 3 feet 2 inches each, with a width of 12½ feet, giving a fire surface of about 80 square feet. Each grate is 1¼ inch thick, having between it and the next one a space of a quarter of an inch wide, giving the whole of the space for the passage of the air to the fires equal to about 10½ square feet. The dampers at the back end of the boilers are usually kept open about four inches, giving an area of four and one-sixth square feet for the exit of the smoke. The upper and lower tiers are connected by thimbles in four places in each boiler between their ends, while at the ends are a number of connections, as shown. The thimbles are of cast-iron, having a socket turned in its upper part, into which a tube is set, reaching to within eight inches of the top of the upper boiler. The connections at the ends are of cast composition metal, and notwithstanding their number no leakages have occurred. A steam drum, 11 feet long and 33 inches diameter, is connected with each of the upper boilers, and is placed above them; from this drum steam is taken to the engines. Accurate measurements and accounts have been kept of the amount of coal used, and of the water evaporated by it, which show that for the last year together, the average amount of water evaporated to one pound of coal consumed was 9.66 lbs.

The amount of coal consumed under each nest of eight boilers per day is about 2½ tons, and by comparing the weekly averages of effect, it appears that, even with this large amount of boiler compared to the fire surface, that the less the amount of coal consumed per day the better the effect.

For example: the amount of coal consumed under two nests of these boilers during the week ending Feb. 18th, 1848, was 65 tons, which evaporated 8.72 lbs. of water for each pound of coal consumed, and during the week ending July 14th, 1848, 21 tons of coal only were burned, and 10.44 lbs. of water were evaporated for each pound of coal consumed. The best result from a week's working was obtained during the week ending May 7th, 1849, when 11.62 lbs. of water were evaporated by each pound of coal consumed.

The steam from two nests of these boilers is used at a pressure of 65 lbs. per square inch, by a double high-pressure engine of 200-horse power, and a single engine of 40-horse power, both of which exhaust into pipes under a pressure of five pounds per square inch, from which it is used for dying, drying, and heating.

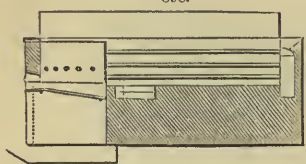
Somewhat similar to the nest boilers are the *elephant* and *retort* boilers. The former consists of two small cylindrical boilers set beneath a larger one, connected by legs at each end, hence probably the

name: the upper boiler being the body, and the connections the four legs. The grate is placed beneath one end, and the fire is brought in contact with the whole surface of the smaller boilers, passes to one end, and returns beneath the bottom of the larger boiler; the legs being sufficiently long to admit a division or arch of brick between the upper and lower boilers. These boilers are very popular in France and on the Continent, but have been used here in few instances. A good proportion for one of these boilers is as follows:—length, 24 feet; upper boiler 4 feet diameter, ends egg shaped; the lower tubes 2 feet 2 inches diameter, and separated from each other about 3 inches; water legs 18 inches diameter, and fire grate 5 feet wide by 6 feet long. The ends of the tubes may be made to project beyond through the brick-work, and have cast iron heads; but the ends of the upper boiler are usually in the flue. At the "India Mill," in Stockport, England, there is one of these boilers 35 feet long by 5 feet diameter in the main barrel; lower tubes, 2 feet 3 inches diameter; water legs, 16 inches diameter and 2 feet 3 inches high. Two of them are capable of exerting about 500 indicated horse power, consuming about 3 lbs. of coal per horse power per hour, and are worked under a pressure of 64 lbs. per square inch.

The Retort boilers consist of several small boilers or tubes, say from 16 to 20 inches diameter, arranged in rows some 2 or 3 inches apart, the spaces being filled in with brick. The steam spaces of these tubes are connected by legs to a steam drum above placed crossways of the tubes. The tubes are short, and are placed crossways of the grate, and the flame is brought in contact with the under surface of the tubes and returned over the top, the one being the water and the other the steam space. In this way the steam becomes super-heated, the intention of the boilers being for the generation of very high steam, as high as 250 lbs. to the inch. Retort boilers somewhat similar to the above were constructed by Dr. Alban on the Continent, of smaller tubes, and worked with much higher pressure.

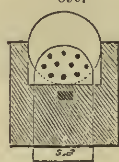
Flue Boilers. Flue boilers are of various forms; the simplest are cylindrical boilers with single or double return flues passing through them. In some the fire is made beneath the boiler at one end, the flame passing beneath the boiler and returning through flues in the boiler to the front end, where the chimney is placed, or making one return through one flue or set of flues, it is again returned by another set to the rear to the chimney. Still in another the boiler is made cylindrical, with the lower half cut away at one end for the reception of the grate, and the flame passes directly through the flues, and returns by one side of the boiler and back by the other, or makes but one return, and that beneath the boiler, the chimney being placed at the front end.

398.



SCALE.—1-20th inch = 1 foot.
Longitudinal Section.

399.

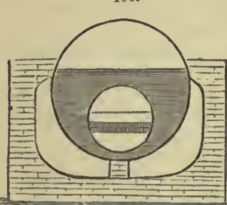


SCALE.—1-20th in. = 1 foot.
Transverse Section.

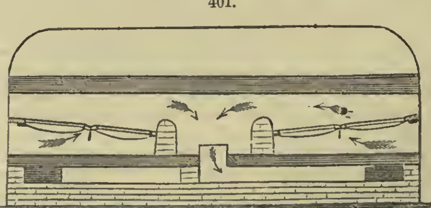
Figs. 398, 399, These flues may be either large and few, or more numerous and smaller; the latter class when tubes are used are called locomotive boilers, although used for stationary purposes. The advantage of this form is, that the hottest part of the flame is brought in contact with the top of the water: desirable whenever the top of the fire-place and flues can be kept covered with water with certainty. The top of the fire-box being a flat or concave surface, it is therefore weak unless very strongly stayed.

The Cornish Boiler, similar to fig. 398, is a cylindrical boiler, with an internal flue or flues passing through the boiler, and thence being returned on one side and back on the other; or making the first return at the sides, is brought back beneath the bottom of the boiler. The diameter of the Cornish boilers is usually about one-sixth of their length, a common proportion is from 36 to 40 feet in length, and from 6 to 7 feet in diameter. The pressure per square inch is from 15 to 35 lbs. The great economy of the Cornish boiler is found in the large proportion of fire in the slow combustion, in the great care taken in firing and keeping a register of the duty, and in the protection of the boiler from radiation.

400.

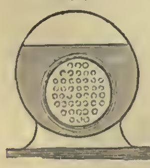


401.

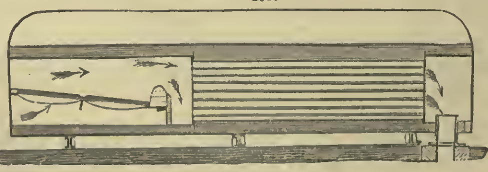


Figs. 400, 401, is a form of boiler prepared and patented by Wm. B. Johnson. The furnaces, two in number, are placed, one at each end of this flue, and the gaseous currents therefrom traverse—as shown by the arrows—meeting and mingling with each other in the central space between the two bridges. There the gasses are well mixed and ignited, prior to the combined current passing off through the outside bottom flues. Figs. 402, and 403, exhibit similar sections of a tubular boiler with a single furnace. The gases here pass from the furnace into the chamber at the back of the bridge, and thence through the flue tubes into an end

402.



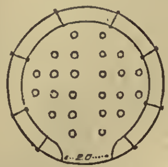
403.



smoke-box, in communication with the chimney flue. The smoke-box has an end door for cleaning, and is well surrounded with water.

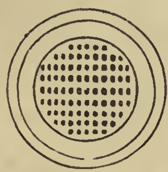
Figs. 404, 405, 406, 407, represent views of an upright tubular boiler well adapted in some situations for stationary purposes.

404.



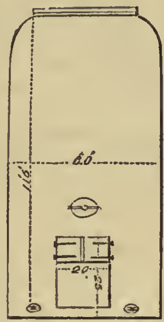
Section through Ashpit, showing stays of bottom water space.

405.

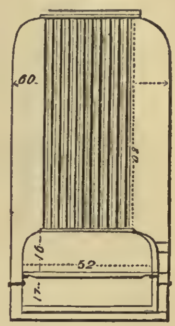


Section through Tubes.

406.



407.



SCALE.—1-8th inch = 1 foot. No. 1. Elevation. Perpendicular Section

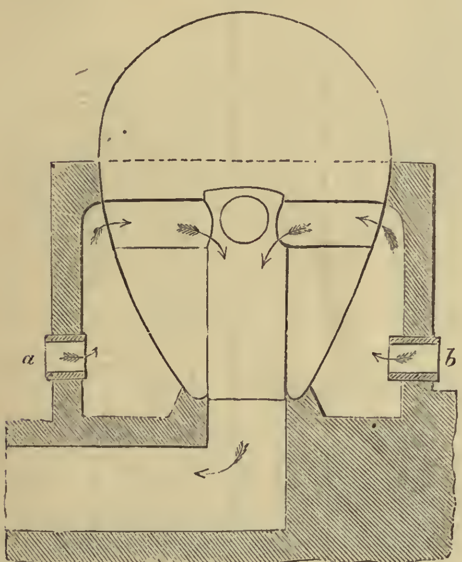
The Egg-Shaped Boiler, Figs. 408, 409. This boiler is known as the "upright egg-boiler," and is much used in Staffordshire, from the circumstance of its being so well adapted to being worked by means of the waste heats of the puddling furnaces. It is not easy to conceive a form of boiler more suitable for such an arrangement, especially where high-pressure steam is required.

Two of these boilers at Messrs. Thorneycroft's Shrubbery Iron-Works, each about 9 feet diameter and 18 high, make sufficient steam to work at about 80 horse-power, entirely from the spare heat or heated gases and smoke proceeding from four puddling furnaces, (two to each boiler,) which heat had previously gone wholly to waste.

From some estimates of the consumption of fuel by Messrs. Thorneycroft's engine, (a 48 inch cylinder,) when worked by boilers of the ordinary horizontal construction, there is every reason to believe that a considerable gain may be made by adopting this construction of boiler generally, for ordinary stationary or manufacturing purposes. Its great economy arises, in a great measure, from the vertical inside flue, the whole of the interior surface of which may be considered as effective in generating steam, in place of the upper half only of the common horizontal flue. And this beneficial efficiency, it is probable, may be further increased, if the lower end of the inside flue was made a few inches wider than the top, thus giving a better position for the generating surface.

a, *b*, *c*, *d*, in the plan show the places, with respect to the inside flues, at which the hot air or flame is discharged from the puddling furnaces.

408.



409.

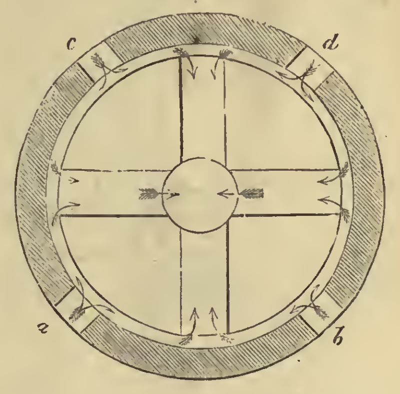
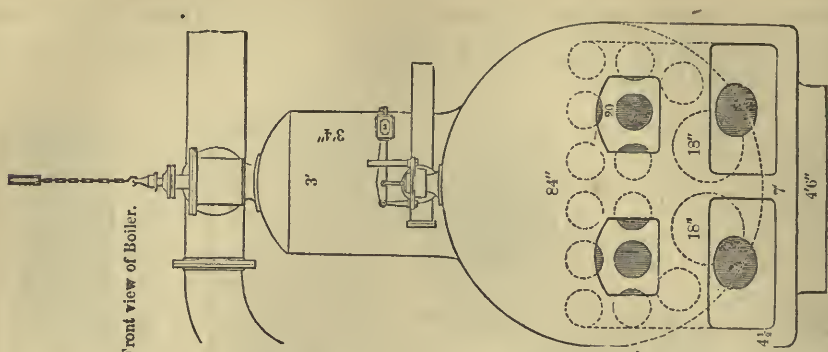
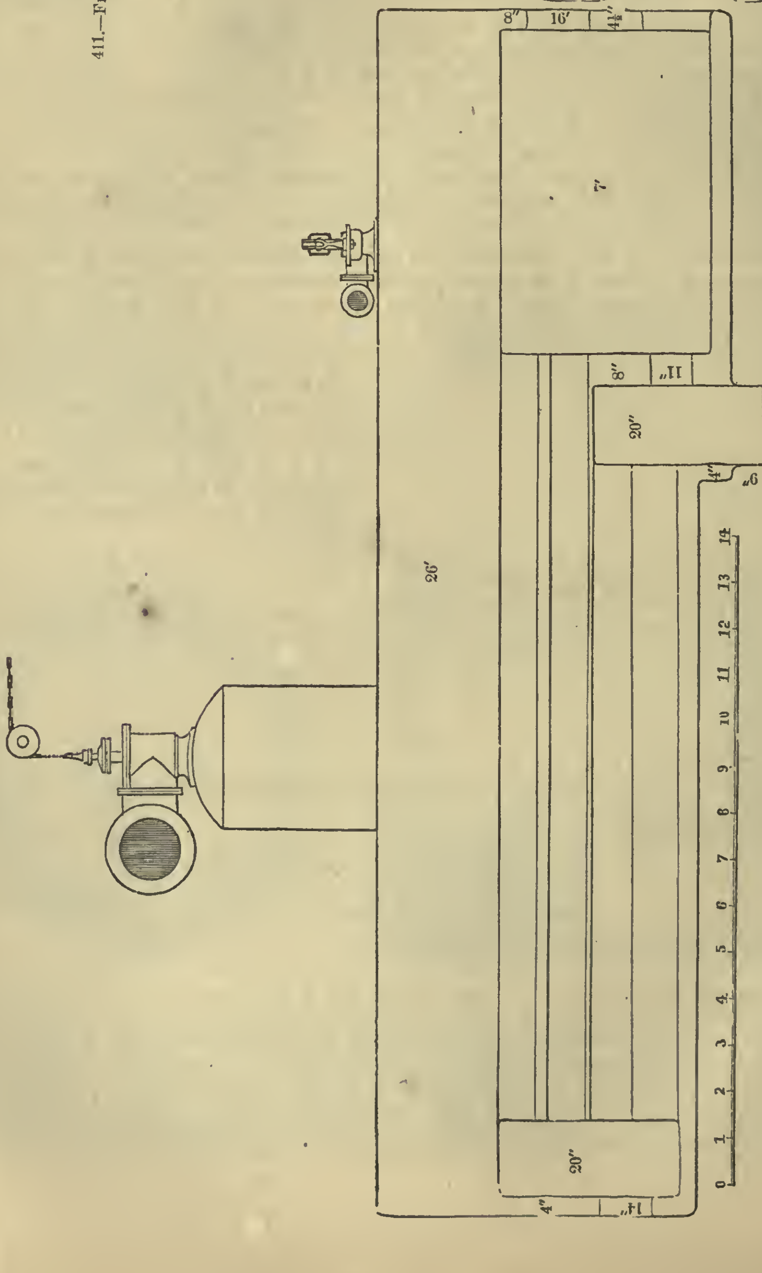


Fig. 410, represents a longitudinal section, and fig. 411, a front view of a single return drop flue, such as is used to drive the pumping engines at the Brooklyn Dry Dock. The boiler itself is 84 inches in diameter; a regular fire-box is made at one end, and the smoke and flame pass through a number of small flues at the upper part of the box, and are returned through larger and less numerous ones at the bottom of the boiler nearly to the fire-box again, where they are taken off laterally into the chimney. All the flues, and boxes at the end of the flues, are included within the shell of the boiler; the boiler is covered with brick-work and ashes. Boilers of this form give very excellent evaporative returns, and are used much in this country both for stationary and marine purposes.

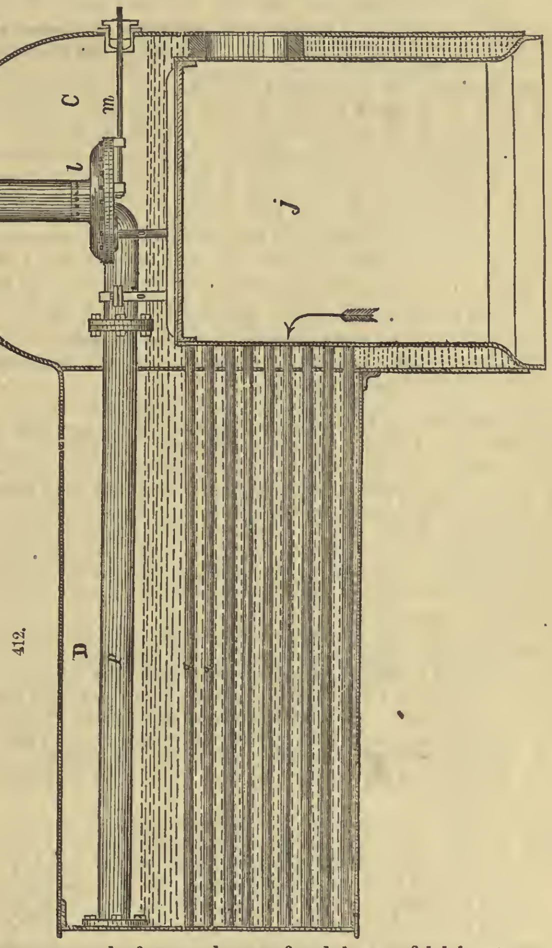


411.—Front view of Boiler.



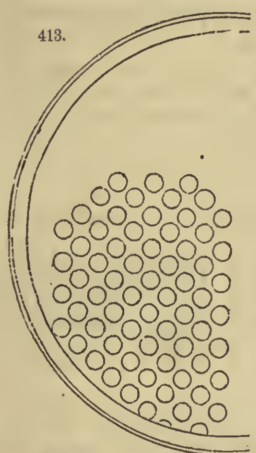
410.—Longitudinal Section of Boiler

The Locomotive Boiler (Fig. 412) represents a section of a common locomotive boiler, and fig. 413 is an end view of one-half of the smoke end. The proportions of locomotives are considerably varied by different makers, but the general arrangement is always preserved. The diameter of the tubes varies from $1\frac{1}{4}$ to 3 inches, and the length of the tubes from 7 to 14 feet. We give the investigations of the Principles of the Locomotive Boiler, by Daniel K. Clark, of Edinburgh, a paper read before the London Ins., C. E., as the most extended and reliable of any yet published; but it must be observed that the engines experimented on were coke engines, a fuel little used in this country; the application of the same principles might not obtain entirely in wood and coal engines. For a comparison of th engines of the different varieties, we subsequently extract from the valuable Report of G. W. Whistler Jr., to the Reading R. R., Pa.



412.

413.



The evaporation of 12 lbs. of water per pound of pure coke was found, by careful laboratory experiments, to be the maximum of evaporative performance; in the best ordinary practice an actual evaporation of 9 lbs. of water per pound of coke, or 75 per cent. of the possible maximum, was readily obtained, the balance being lost by leakage of air and by waste; and it was adopted by the author as the ordinary standard of practical economical evaporation.

A minute analysis was made of the results of numerous authenticated experiments on the evaporative power of locomotive boilers, of very various proportions, on the engines of the Caledonian, Edinburgh, and Glasgow, and Glasgow and Southwestern Railways. It was concluded, that the economical evaporative power of boilers was materially affected by the area of the fire-grate, and by its ratio to the whole heating surface; that an enlargement of the grate had the effect of reducing the economical evaporative power, not necessarily affecting the quality of combustion in any way, but governing the absorbing power of the boiler, as the lower rate of combustion per foot of grate due to a larger area, in burning the same total quantity of fuel per hour, was accompanied by a reduced intensity of combustion, and by a less rapid transmission of heat to the water, in consequence of which a greater quantity of unabsorbed heat must escape by the chimney. An increase of heating surface again, reduced the waste of heat, promoted economy of fuel, and added greatly to the economical evaporative power. In short, the question resolved itself into the mutual adjustment of three elements—the neces-

sary rate of evaporation, the great area, and the heating surface, consistent with the economical generation of steam at the assumed practical standard of 9 lbs of water per pound of good coke. An investigation of the cases of economical evaporation, in the "Table of Experiments," conducted the author to the following important equation, expressing the relation of the three elements of boiler-power; in which c was the maximum economical evaporation, in feet of water per foot of grate per hour; h was the total heating surface in square feet, measured inside; and g was the grate-area in square feet.

$$c = \cdot 00222 \frac{h^2}{g}$$

From this it followed: 1st, that the economical evaporative power decreased directly as the area of grate was increased, even while the heating surface remained the same; 2d, that it increased directly as the square of the heating surface, when the grate remained the same; 3d, that the necessary heating surface increased only as the square root of the economical evaporative power; 4th, that the heating surface must be increased as the square root of the grate-area, for a given evaporative power. It was contended thence, that the heating surface would be economically weakened by an extension of the grate, and would be strengthened by its reduction; and that whereas large grates were commonly thought to be an unmixed good, and being generally recommended were usually adopted, still they might be made too large—not that their extension affected the quality of combustion, but that the economical evaporative power might be reduced. Concentrated and rapid combustion was alike the true practice for the largest and the smallest boilers; and, in locomotives where lightness, compactness, and efficiency were primary objects, the boilers should be designed for the highest average rates of evaporation per foot of grate that might be followed in good practice, consistently with the highest average rate at which coke could be properly consumed; as, in this manner, the smallest grate and the smallest amount of heating surface consistent with good practice might be employed. It was stated that 150 lb. to 160 lb. of good sound coke could be consumed per foot of grate per hour; and, allowing for inferior fuel, an average maximum of 112 lb. per foot of grate was recommended as a general datum. This determined the average maximum of economical evaporation to be 16 feet of water per foot of grate per hour, allowing 9 lb. of water per pound of coke; for which 85 feet of heating surface per foot of grate should be provided. It was accordingly recommended that a heating surface at least 85 times the grate-area should be adopted in practice.

Such experiments as "midfeathers," &c., which were resorted to for specially increasing the fire-box surface, were condemned, as they were considered to be no better than tubes, whilst practically they were inconvenient and costly; as, among other reasons, plates of $\frac{7}{16}$ inch or $\frac{1}{2}$ inch in thickness were employed to do the work of the tubes, which were less than $\frac{1}{8}$ inch in thickness.

A practical rule followed by some engineers, and stated to be founded on extensive experience, was to allow 5 feet of heating surface for 1 foot of water evaporated per hour, and 100 feet of evaporating surface per square foot of grate. Those results were found to agree with the maximum rates recommended in the paper. It was also argued that the intensity of combustion materially affected the amount of heating surface necessary for economical evaporation, being less as the intensity was greater. It was contended, on the other hand, that the formula as stated in the paper would not apply to all engines.

It was further argued that, from various causes, no formula could be framed to be of service unless all the circumstances in each case were properly taken into account.

As an example of the objections to long tubes, the results were given of the work done by a luggage engine on the London and Northwestern Railway, before and after alteration. That engine originally had tubes 14 feet long, with a total surface of upwards of 800 feet; the length of the tubes was diminished to 4 ft. 9 in., and the total surface was reduced to about 500 feet, when it was found that a saving in fuel of 40 per cent. per ton per mile moved was produced, with a saving of 23 per cent. per mile run; the coke used per ton per mile, with long tubes before alteration, being ·504 lb., and with the short tubes, ·298 lb.

The back pressure was contended to be a serious drawback to the long-tube engine, and an example was given of a trial of a single engine on the new plan, against two of the ordinary kind, of 170 tons in both casts, and, although the single engine was 43 per cent. less powerful than the two engines together, and had 20 per cent. less heating surface, yet it had performed the same distance of 111 miles in ten minutes less time, and with 3 lb. per mile less fuel. This, it was argued, was owing to the engine exerting a greater dynamic force, by being relieved from the back pressure of the blast-pipe, which in the case of the other two was applied to force the fire, and to draw the heated air through the long tubes.

By the mode of placing the tube plate some distance within the cylindrical part of the boiler, the tubes were not liable to be choked with cinders, or the draught to be obstructed. This plan also afforded an opportunity of reducing the size of the tubes from $1\frac{7}{8}$ inch diameter to $1\frac{5}{8}$ inch, giving in the same boiler an equal area of flue passage, whilst at the same time the proportion of tube heating surface was increased 34 per cent. per foot of length of tube, and a very large addition of flame surface was gained.

It was further argued that although the evaporation of water per lb. of fuel was the test of the boiler, yet up to this time, few if any experiments could be implicitly relied upon, owing to the quantities being estimated by measurement instead of by weight, and without due regard to the variation of the temperature of the water in the tender.

As to the evaporative powers of marine boilers as compared with that of the best locomotive boilers, if an investigation was instituted it would be found that the general features of the best tubular marine boilers now used in ocean navigation were nearly identical with those of locomotive boilers, but the circumstances under which they were used were very different. In the marine boilers, coal was used instead of coke, and the natural draught of the chimney instead of the urging of the blast-pipe in a

locomotive, worked for many weeks or months consecutively, without the means of stopping for any extensive repair, or even to be cleaned except at long intervals. The following statement showed the comparative proportions and effect of the two descriptions of boilers:

In the Locomotive Boiler,

1 square foot of firegrate consumed about 112 lb. of coke per hour.
1 square foot of firegrate required about 85 square feet of firebox and tube surface.
1 square foot of firegrate with the above surface would evaporate 1008 lb. of water per hour.
1 square foot of flue surface would evaporate 11·7 lb. of water per hour.
1 lb. of coke would evaporate 9 lb. of water.
1 H. P. of 33,000 lb. lifted 1 foot high per minute, required about 4 lb. of coke per hour.

In the Marine Boiler,

1 square foot of firegrate consumed about 20 lb of coal per hour.
1 square foot of firegrate required about 30 square feet of fireplace and tube surface.
1 square foot of firegrate with the above surface would evaporate 170 lb. of water per hour.
1 square foot of flue surface would evaporate 5·66 lb. of water per hour.
1 lb. of coal would evaporate 8·5 lb. of water.
1 H. P. of 33,000 lb. lifted 1 foot high per minute, required about 4·25 lb. of coal per hour.

From this statement it appeared that although the proportion between the firegrate and the flue surfaces was widely different, the quantity of water evaporated, and the power obtained by the consumption of a given weight of fuel, was nearly the same, when allowance was made for the difference in the evaporative power of coal and coke. The possible maximum evaporative power of 1 lb. of carbon, was deduced from the results of chemical experiments, showing that 1 lb. of carbon, converted into carbonic acid, developed 14,000 units of heat, or would raise 14,000 lb. of water through 1°, which was equivalent to the conversion of 12 lb. of water at 60° into steam of 120 lb.

A comparison was drawn between the recent experiments of Mr. Marshall, on the large firebox engine, and those on the long boiler engine, made during the Gage Inquiry, the results being with the former a consumption of 40 lb. per mile with an average load of 64 tons, and with the latter a consumption of 27 lb. per mile with a load of nearly 60 tons. The recorded results of the work of the passenger trains on the Eastern Counties line, for the last half year, showed an average consumption of coke under 18 lb. per mile run.

It was contended, that hitherto no advantages had resulted from the extension of the firebox and the reduction of the length of the tubes, still it was possible that this innovation might, by directing attention to the subject, lead to important modifications of the structure of locomotive boilers, which should possess compactness, lightness, power of raising sufficient steam with rapidity, for performing the required work, strength to resist the chance of explosions, and a form calculated to diminish the disastrous effects of explosions when they occurred, facility of repair, especially of the firebox, which was the part most liable to deterioration, being most severely acted on by the fire, and also requiring more support than the tubes, the latter being at the same time cheaper and of thinner metal, whilst by an extension of their length the diameter of the external shell of the boiler could be diminished; the firegrate should not be larger than would evaporate the required quantity of water into steam, within a given time, with the utmost practical economy of fuel, and if that were accomplished, it was of little importance whether the evaporating heat was communicated through the firebox or by the tube surface; and that up to the present time the results of the experiments upon the boiler with enlarged firebox and shortened tubes, exhibited rather a retrograde step than an onward progressive movement.

From the "Report of G. W. Whistler, Jr.," upon the use of Anthracite Coal in Locomotive Engines on the Reading Rail Road, made to the President and Directors of that company, in 1849, we extract the following:

Tabulated Comparison of Engines on Reading R. R.—Fuel Consumed.

Class of Engines.	Number and diameter of driving wheels.	Weight on driving wheels—tons.	Coal transported per trip—tons.	Total gross load per round trip—tons.	Tons of coal transported pr. t'n of adhesion.	Fuel cons'm'd pr. r'nd trip of 190 miles.	Water evaporated.
Baltimore Anthracite Engines.	8.–46 in.	25	450	900	18	9 tons coal.	14,400 galls.
Wood Engines, Large.	8.– "	22.5	420	840	18·66	13.75 c'ds w'd	16,200 "
" " Small.	6.– "	19.5	375	750	19·23	13. " "	

The total weight of the Baltimore engines with coal, fuel and water, 27 tons; weight on eight driving wheels, 25 tons; do. on two small trailing wheels, 2 tons; diameter of the boiler, 42 inches length of tubes, 14 feet; diameter do. 2⅛ inches; area of grate, 18 feet; fire surface, 957 feet; diameter of cylinders, 16·5 inches; length of stroke, 20 inches. The draft is regulated by the variable exhaust in the smoke stack—steam cut off at half stroke.

The large 8 wheeled wood engines—total weight 22·5 tons; cylinders 15·5 inches in diameter; 20 inch stroke; fire surface about 875 feet; and of grate about 12 feet.

The essential point in which the Baltimore engines differ from the wood engines is in their having a much larger fireplace and area of grate for the combustion of coal.

The principal item of excess of cost for repairs of engines burning coal over those burning wood, is caused by the destructive effects of a coal fire upon the inside sheets of the fire-box; and when iron, (the soundness of which is always uncertain from the manner in which it is at present made,) has been used entirely for fire-boxes, the intense local heat has very soon blistered and burned away the sheets in the immediate vicinity of the coal fire. Another destructive effect from the use of coal is its severity on the laps or joinings of sheets in the fire place. To obviate this, copper sheets were substituted for iron for a distance of two feet above the grate. The experience on the Reading Railroad with anthracite coal has developed a rapid and unexpected destruction to the copper sheets, from the mechanical action of sharp particles of coal, which fleck off from the fresh coal when suddenly heated, and impinge upon and cut away the copper sheets forming the sides of the fire-place. The extent of this mechanical action is very limited, about fourteen inches in width through the entire length of the fire-place, seven inches above and the same below the surface of the coal fire. In the line of the stay bolts both vertically and horizontally, the copper retains its original thickness; and upon the copper sheet below the tube or flue sheet there is no indication of wear, for the particles of coal which are carried towards the tubes bank against, and protect this sheet. On the "Baltimore" the copper lasted fourteen months, about one third of the time experience had proved similar fire-places to last in engines burning bituminous coal on the Baltimore and Ohio Railroad. In addition to the extra wear of fire sheets, the occasional melting of grate bars, the increased liability to leakage, the wear and destruction to the ends of the tubes by caulking, &c., and the accumulation and igniting of fine coal in the smoke box, all produce their share of extra expense for repairs over wood burning engines.

Experience of the Baltimore and Ohio Railroad in the use of coal for locomotive engines.

Table showing the amount of Fuel consumed on the Baltimore and Ohio Railroad, at different periods from 1833 to 1848.

Date.	Weight of Engine on Driving Wheels.	Position of Boiler.	Gross loads.	Miles run.	Fuel consumed.
1833	4 Tons	Upright	23 Tons	80	1.15 Tons Anthracite.
1834	7.5 "	"	45 "	80	1.25 " "
1838	8.5 "	"	50 "	60	1.5 " "
1840	10.5 "	"	60 "	60	1.25 " "
1840	10.5 "	"	60 "	60	1. " Bituminous.
1841	9.75 "	"	60 "	80	1.65 " "
1841	6.5 "	Horizontal	40 "	80	2.05 Cords of Wood.
1841	19.33 "	Upright	140 "	80	3.13 Tons Bituminous.
1841	8.25 "	Horizontal	60 "	80	3.13 Cords of Wood.
1845	23.5 "	"	225 "	80	3.25 Tons Bituminous.
1848	10.5 "	Upright	60 "	80	1.25 " "
1848	10. "	Horizontal	60 "	80	1.03 " "
1848	10. "	"	60 "	80	2.75 Cords of Wood.
1848	10. "	"	60 "	80	1.58 Tons of Coke.
1848	23.5 "	"	200 "	80	2.25 " Bituminous.
1848	23.5 "	"	275 "	98	2.5 " "

1 ton of Bituminous coal = 1.25 tons Anthracite coal.
1 ton of Bituminous coal = 2.12 Cords of Wood.
1 ton of Anthracite coal = 1.75 Cords of Wood.

By an examination of this table, it will be seen what experience alone can do in reducing expenditures; for it will be easy to detect the same engine through a period of years, and see her progressive economy in the consumption of fuel. Time and experience alone have accomplished this, and much may be expected for the Reading Railroad, when by a more general use of anthracite coal, it shall be regarded less as a matter for experiment, than an important element of railway success to be perfected with care and attention.

Extra cost per year over Wood Engines for each 23.5 ton Coal Engine on the Baltimore and Ohio Railroad from the use of Bituminous Coal:

Cost for renewing fire-place	$100.00
Two sets of fire bars, 1000 lbs. cast iron, at $2\frac{1}{2}$ c.	25.00
Renewing ends of Tubes, caulking, &c.	100.00
Extra work, caulking, &c.	25.00
	$250.00.

By these experiments and dates from the Reading and from the Baltimore and Ohio Railroads, it was satisfactorily proved, even at the date of the report, 1849, that in an economical point of view coal engines are superior to those burning wood. Since that time further improvements have been made, and at present almost the entire hauling of the Baltimore and Ohio, the Reading, the Pennsylvania Central and their connections, and the Branch Coal Railroads, is performed by coal engines, either anthracite or bituminous.

Marine Boilers.—We are very much in the dark as to the true principles upon which to design a marine boiler, which shall produce the greatest effect with the least stowage, and first cost, subsequent labor, and fuel. The best that can be done is to determine which of these considerations shall have the least weight, and to be governed accordingly, looking as a guide to practice, rather than any assumed theoretical principles. The object aimed at in marine boilers is, in general, to reduce the space occupied by the boilers to the least possible, consistent with the effect to be produced, and at the same time not to lose sight of the necessity for proper space for cleaning and repairing. A certain proportion between the area of the grate and the total heating surface has been found productive of the best re-

sults, with a given description of fuel, but an alteration in the quality of the fuel used will oe found to affect this result materially.

Again, the famed Cornish boiler, which has exhibited the greatest amount of work with the least fuel, is arranged on the principle of slow combustion, and an extended flue surface, while the locomotive boiler, on the contrary, is dependent for its effect upon a quick combustion and a short and direct draught. Hence we see the improbability that any one form of boiler will ever be likely to fulfil all the varied conditions under which they may be placed. As before remarked, for stationary boilers the general proportions have been measurably determined—that is to say, for every cubic yard of capacity in the boiler, there shall be a square yard of fire-surface, and a square foot of fire-grate, and one-half the contents of boiler to be water, and the other half steam room. These proportions have given good results, but are too bulky for economical stowage on shipboard, and as constructed for land use, are deficient in steam power.

Marine boilers are of necessity either flue or tubular boilers, since the flame must be within the shell of the boiler ; but in this arrangement they are almost as various as the makers. The evaporation of marine boilers per lb. of coal is considerably less than that of stationary boilers; reckoning the latter at from 8 to 10 lbs. of water evaporated per lb. of coal, that of marine boilers will be from 6 to 8. The proportion of fire surface to grate, taken from an average of 65 boilers in Bartol's Marine Boilers, is 28 to 1; of grate to area of chimney, 6.3 to 1; the amount of coal consumed per hour per square foot of grate, 26 lbs. The boilers from which an average is thus taken include about all the varieties used on our river and ocean boats, and of which we now proceed to give examples of some of the most important.

BOILERS, *American.* The intense heat produced by anthracite coal cannot be observed in steam-boilers, except by its effect in the amount of steam generated.

Many persons, remarking the much greater volume of flame in puddling and other furnaces, have attributed the difference to the superior arrangement of the furnaces, and have anticipated great results from the adootion of the same plan in steam-boilers.

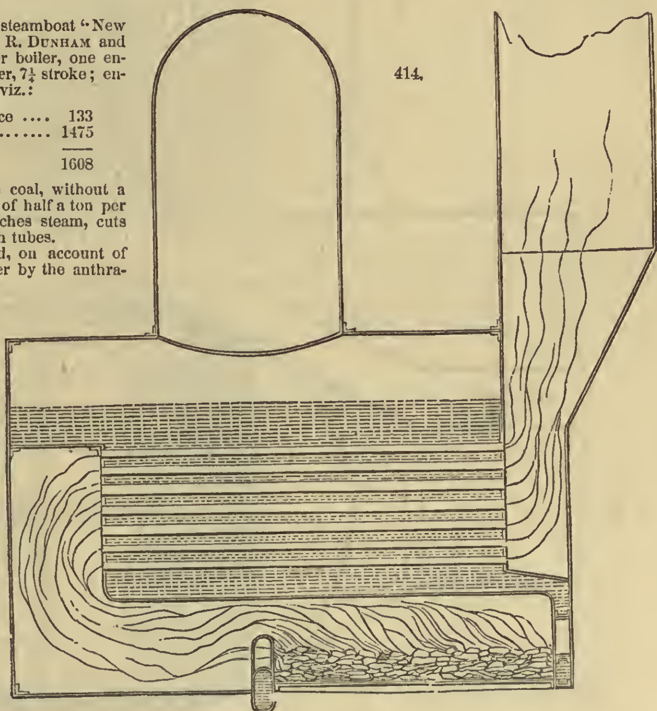
[Fig. 414. The steamboat "New York," built by H. R. Dunham and Co., has one copper boiler, one engine, 40-inch cylinder, $7\frac{1}{4}$ stroke; entire surface, $1608\frac{1}{4}$, viz.:

Direct or furnace	133
Tubular	1475
	1608

Burns anthracite coal, without a blower, at the rate of half a ton per hour; keeps 12 inches steam, cuts off at $\frac{1}{2}$; 250 $2\frac{3}{4}$-inch tubes.

Now burns wood, on account of injury to the copper by the anthracite.]

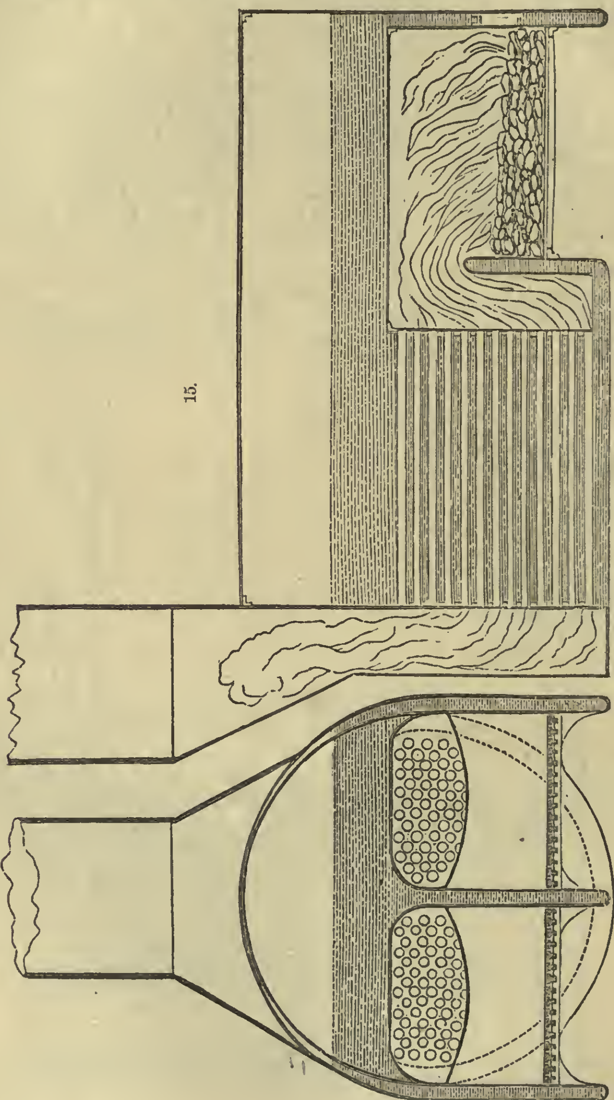
414.



This erroneous conclusion is the result of ignorance, or of inattention to the fact that in steam-boilers the flames are partially extinguished by coming in contact with surfaces, comparatively cold, highly conducting, since the heat of the metallic plates of the boiler can never be much above the boiling point of water; whereas, the walls of the furnace being non-conductors, and of consequence almost of the temperature of the furnace, inclose all the heat, and produce naturally a different appearance in the flame. The intensity of the heat generated in any furnace or boiler by a given amount of fuel, depends alone upon the velocity of the current of air; or, in other words, upon the amount of oxygen brought into contact with it, without any reference whatever to the way in which the heat so generated is dissipated or disposed of.

STEVENS' *boilers.*—A complete revolution has taken place during the last ten years in the form of the boilers of steamboats plying on the lakes and rivers of the Northern States; this change is the result of the introduction of anthracite, and the many experiments made to discover that form of grate and boiler best adapted to its combustion.

The editor has collected, with considerable labor and care, all the best forms, selecting such only as experience has approved and extensively adopted. These are laid down in as plain a manner as pos sible, sections of each showing their general structure.



415.

416.

[Figs. 415 and 416 are copper boilers, 8 feet, made by H. R. DUNHAM and Co., for steamboat "Independence."]

In the year 1837, Robert L. Stevens, Esq., constructed a pair of boilers, of tubular form, for his steamboat "Independence," plying between South Amboy and New York, of which Figs. 415 and 416 are correct representations, the form of which was well adapted to the burning of the new species of fuel by the assistance of bellows, or what is ordinarily termed the fan.

No difficulty was ever found in the accomplishment of the purpose they were intended to effect, and though many improvements have since that time been adopted, they are still working satisfactorily.

To Mr. Stevens belongs the credit of first establishing the water-bridge; which serves the purpose of protecting the mouth of the tubes, and preventing the heat of the furnace from burning them out. This is one of the most important features of Mr. Stevens' arrangement, and has since been adopted by many other engineers.

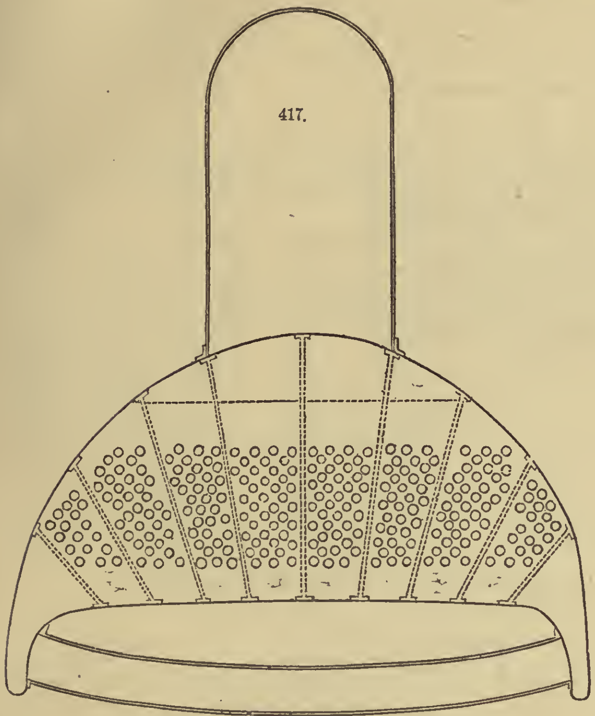
Another curious and useful form of boiler is shown by Fig. 414, two of which were built by Mr Stevens for the steamboat "New York."

The shell or crown is nearly of the form of a parabola, beautifully adapted to the end designed. See Fig. 417.

With a very great expansion of surface and great breadth of furnace below, there being a small quantity of water for so large a generating surface, saving a great deal of weight, which is of great importance, particularly in river boats, this boiler has the advantage of being easily *braced*, and the centre of gravity being very low down,—a happy and important arrangement in the boats on the Hudson, in which the boilers are placed on the guards of the boat on deck.

Several examples are added to illustrate similar and other methods.

417.



419.

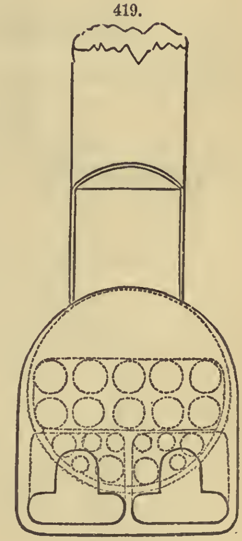
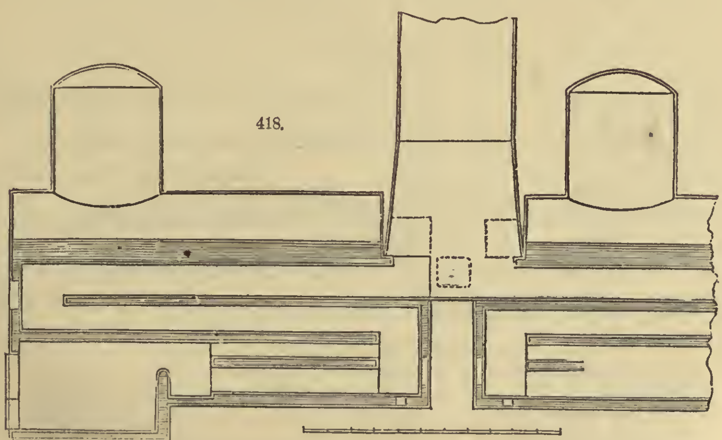


Fig. 417 is a boiler, built by H. R. Dunham and Co., for steamboat "New York."

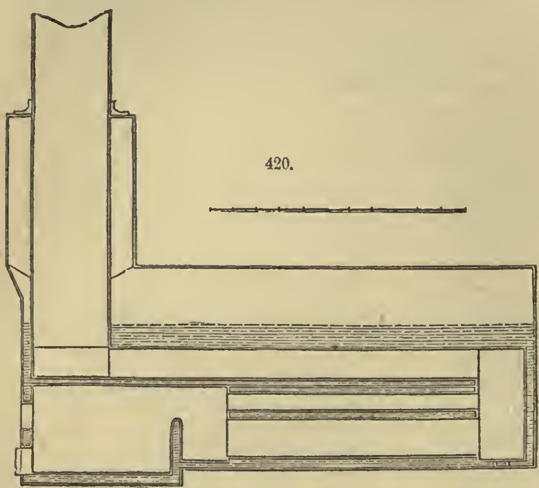
418.



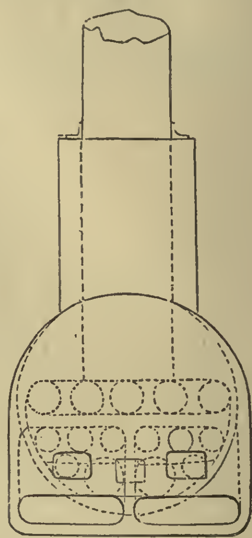
Four of this, Figs. 418 and 419, for steamboat "Empire," built by T. F. Secor and Co., which has two engines, each of 48-inch cylinder, 12 feet stroke, and uses anthracite coal, with blowers.

Figs. 420 and 421. The steamboat "Belle", built by T. F. Secor and Co., has 1 engine of 50-inch cylinder, 10 feet stroke; 136 cubic feet in cylinder, which gives, in proportion to the boiler, $11\frac{32}{136}$ to 1 Uses anthracite, with a blower.

420.



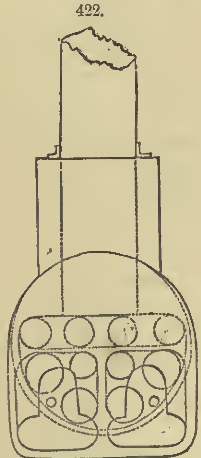
421.



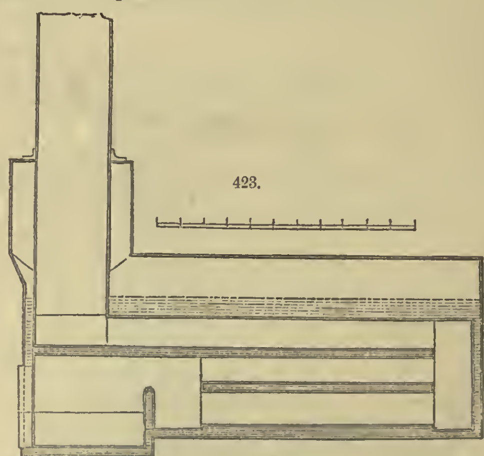
Fire surface in this boiler.

In the steam chimney	12·000
" front connection	85·039
" return flues	477·062
" back connection	114·000
" main flues	621·028
" furnace, bridge-wall, &c.	218·052
Total number of square feet in boiler	1528·081

422.



423.



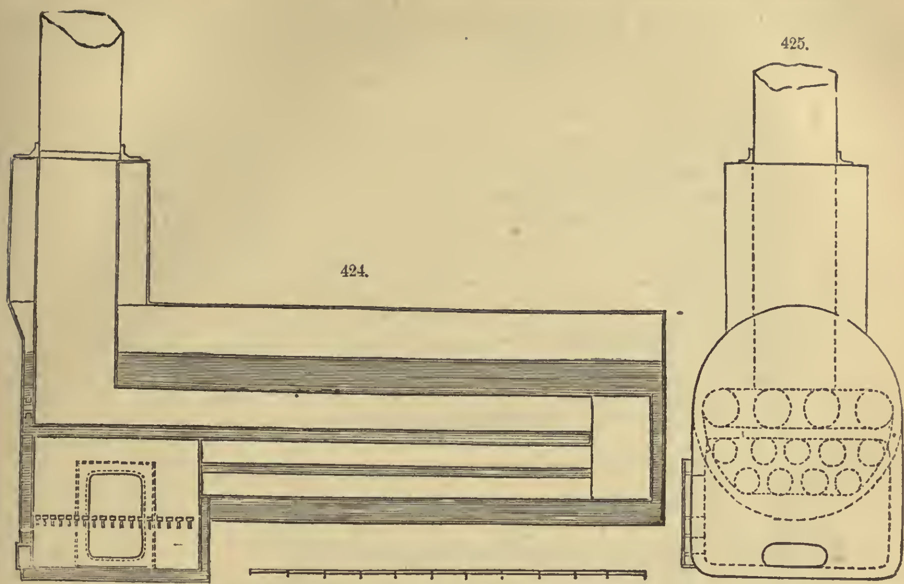
Two of this, Figs. 422 and 423, are in use in the steamboat "Columbia," built by T. F. Secor and Co. She has one engine, 43-inch cylinder, with 11 feet stroke. 111 cubic feet in cylinder, which gives $15\frac{50}{111}$ to 1. Uses anthracite, with blowers.

Fire surface in this boiler.

In the furnace, &c.	163·028
Main flues	311·000
Back end connection	75·087
Return flues	241·014
Front connection	63·107
In the steam chimney	7·065
Total number of square feet in boiler	860·391

425.

424.



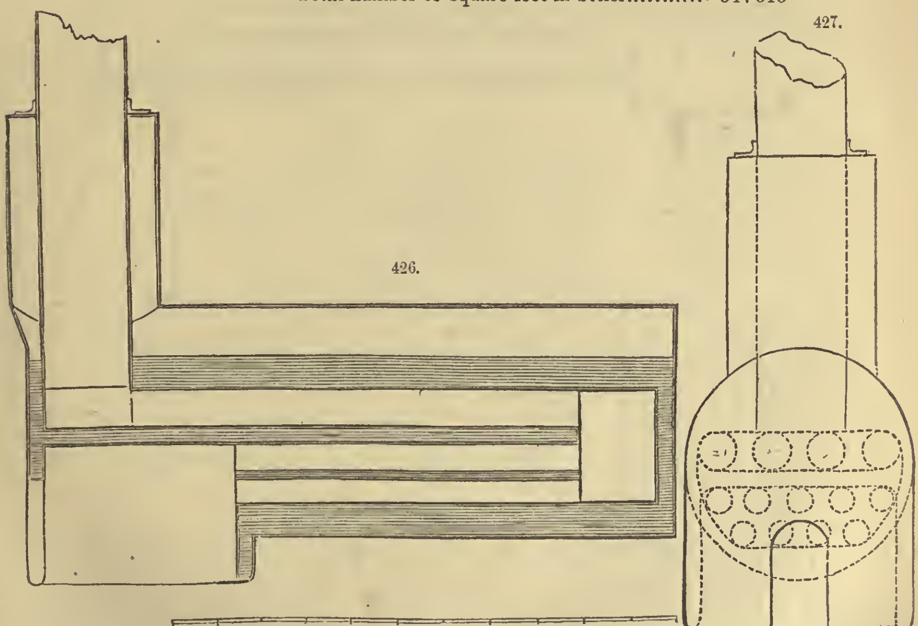
One of this, Figs. 424 and 425, for two high-pressure engines, built by T. F. Secor and Co., in use for a screw propeller boat, with 20-inch cylinders, and 2 feet stroke. 8 cubic feet in cylinders, which gives 68 to 1. Uses anthracite, with blowers.

Fire surface in this boiler.

Furnace	59·103
Main flues	228·081
Back end connection	48·045
Return flues	179·072
Front end connection	29·110
Steam chimney	4·104
Total number of square feet in boiler	547·515

427.

426.



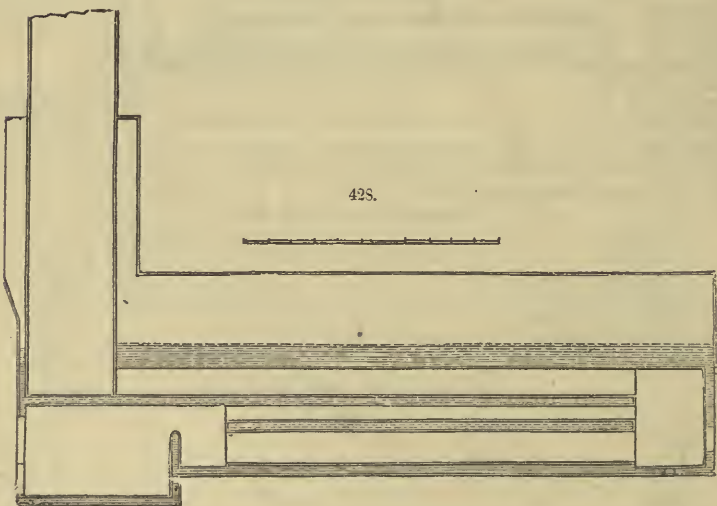
Two of this, Figs. 426 and 427, in use on steamboat "John Mason," built by T. F. Secor and Co., has one engine of 25½-in. cylinder, with 6 ft. stroke. Estimated weight of each, 8834 lbs. Estimated fire surface, 347 square ft. 21 cubic ft. in cylinder, which gives 33 to 1. Uses anthracite, without blowers.

Two of this, Figs. 428 and 429, used for steamboat "Troy," built by T. F. Secor and Co., has two engines of 44-inch cylinder, and 10 feet stroke. Uses anthracite.

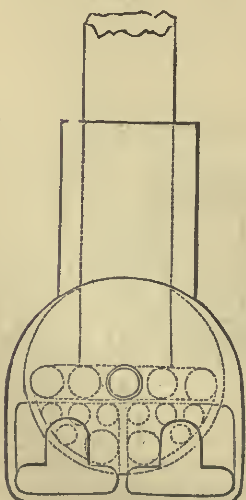
Fire surface in this boiler.

Front of furnace	18·90
Sides of ditto	85·00
Top of ditto	76·50
Bridge-wall	18·00
Between bridge-wall and flues	20·00
Between flues, back and front	17·26
Large flues	167·32
Small ditto	408·60
Return ditto	471·50
Steam chimney	10·40
Back end	25·10
Connection around flues	102·00
Front of return	52·50
Return	11·20
Fire surface of this boiler	**1483·32**

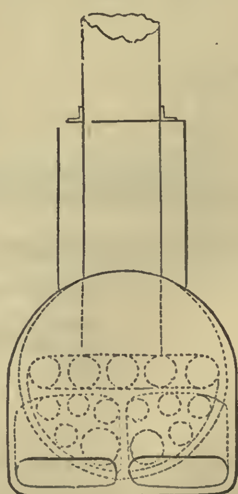
428.



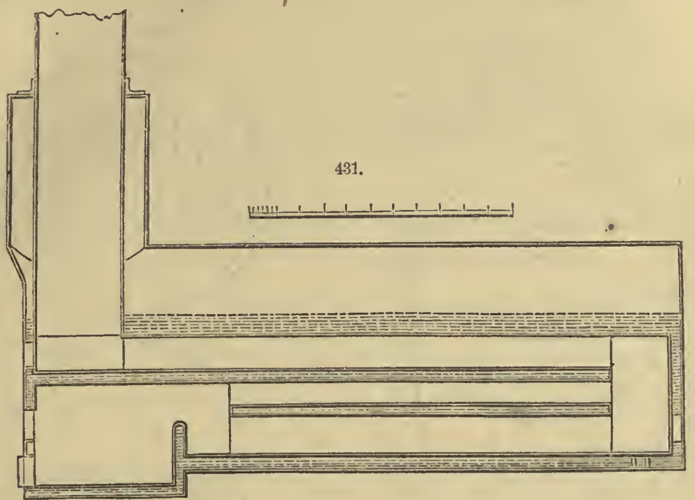
429.



430.



Figs. 430 and 431. The steamboat "Globe," built by T. F. Secor and Co., has one engine of 41-inch cylinder, with 11 feet stroke. 100 cubic feet in the cylinder, which gives $10\frac{19}{100}$ to 1.
Uses anthracite coal, with a blower.

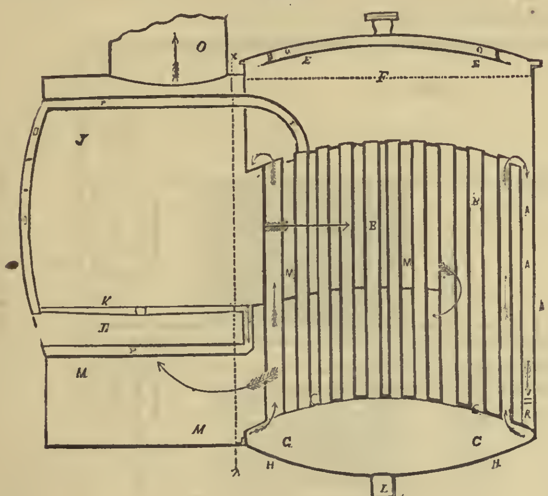


Improvements in steam-boilers—By James Montgomery, Memphis, Tenn. These improvements have in view an economical mode of using the fuel; the establishing of a perfect circulation of the water through the tubes; the depositing of sedimentary matter in a receptacle below the fire, and the preventing of the passing of water, from foaming or other causes, into the steam-pipe and cylinder.

Fig. 432 is a vertical section through the centre of the boiler, and through the furnace attached thereto.

Fig. 433 is a view of a part of the boiler, supposing the furnace part to be removed, and a vertical section to be made of the sectional part in the line X X of Fig. 432 and at right angles thereto

432.



433.

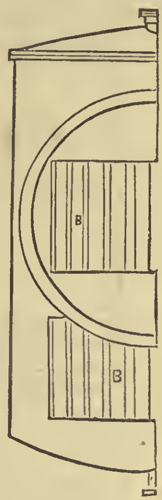


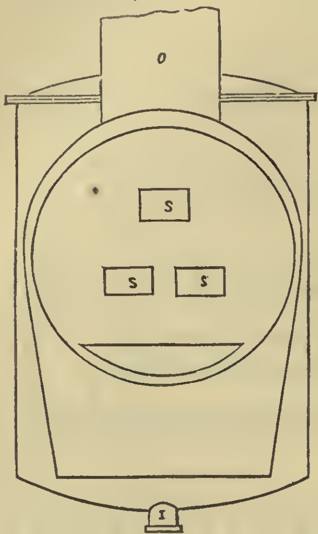
Fig. 434 is a top view of the termination of the boiler-tubes, and of the shell of case by which they are surrounded.

Fig. 435 is a front view of the furnace and boiler. In each of these figures, where the same parts occur, they are designated by the same letters of reference.

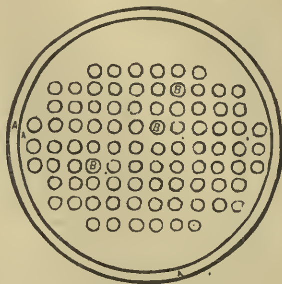
The boiler, in that part which surrounds the tubes, is formed of two concentric vertical cylinders, excepting where the heat and flame from the furnace is introduced, and where the gaseous products of combustion escape to be conducted off by the flue. A is the outer, and A[1] the inner shell of the boiler, with a water space A[2] between them. B B are the tubes, which pass through, and are made fast to

two heads, C C and D D, that are convex upwards. E E is the steam space, and F the water line. G G is that part of the boiler which is below the lower tube-head C C, and H H the bottom of the boiler. This bottom is convex outwards, and may be either spherical or conical; and as the direct heat from the fire is never applied to this bottom, the water contained between it and the lower tube-head C C is in a state of comparative quiescence, in consequence of which the sedimentary matter which

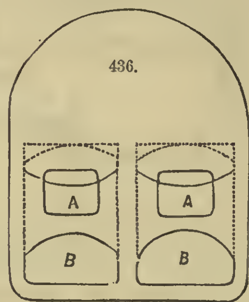
435.



434.



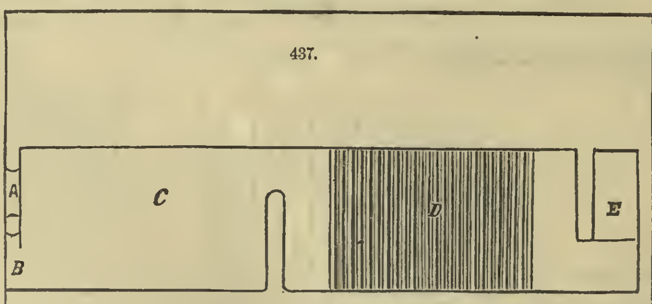
436.



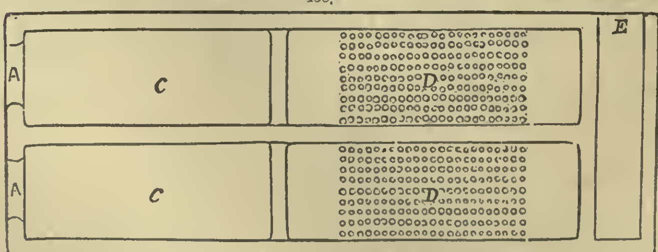
forms incrustations on the bottom and other parts of boilers, as ordinarily constructed, will settle down in this part in a loose unaggregated state. At I, in the centre of this bottom, is placed a blow-off valve, denominated a mud-valve, and which may be opened when requisite, for the purpose of blowing off the accumulated sediment, which it will do effectually without occasioning any considerable waste of water.

J J is the fire-chamber of the furnace, K the grate-bars, and L the ash-pit.

437.



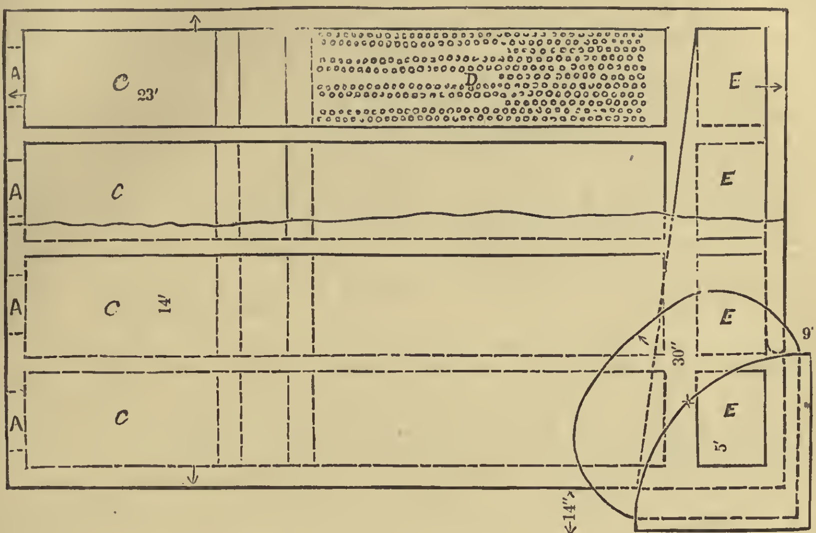
438.



The furnace is placed in such a manner as that the direct heat from it shall enter among the tubes B B, at their upper section, above a diaphragm or partition M M, over which the draft will pass as indicated by the arrows, and then into the lower flue space M' M', and around the furnace to the chimney O

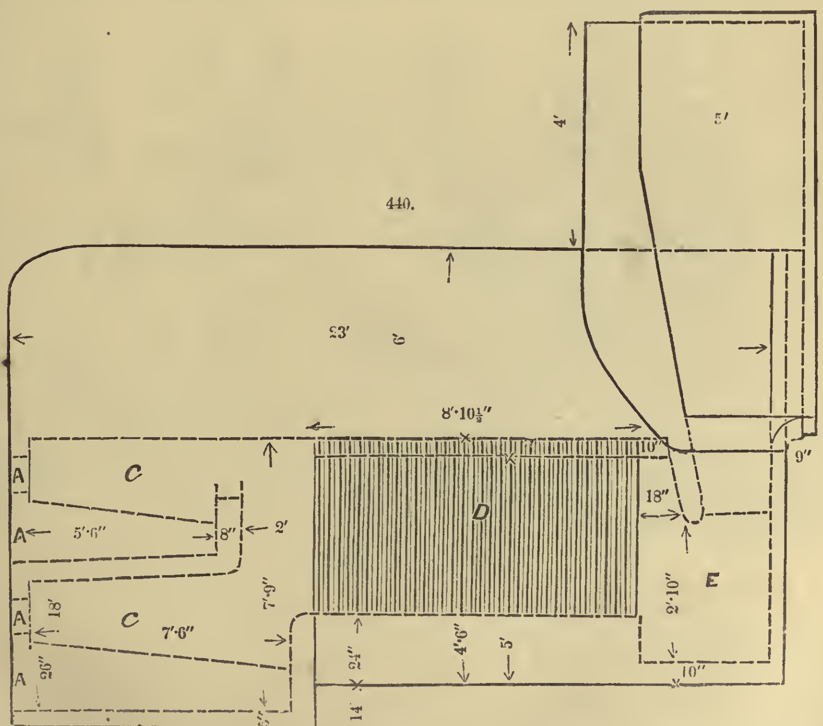
The furnace is surrounded with a water space P P, which communicates with the water in the boilers. This furnace may be placed lower down if desired, and the heat be made to impinge directly on the lower part of the tubes, but we are well assured that the arrangement as represented will be found to be the best.

439.



Below the upper head of the boiler is placed a metallic shield Q Q, leaving an annular steam space of a few inches around it, which will, in a great degree, repress the foaming of the water when the pressure is taken off by the admittance of steam into the cylinder, and will thereby prevent the injuri-

440.



ous, and frequently destructive, result of the entrance of water with the steam. Under this arrangement of the shield, the steam is drawn equally from all parts of the circumference of the boiler.

The production of a free and perfect circulation of the water in a boiler has frequently been aimed

at, but has not, we believe, been heretofore attained. But by this plan of arranging the parts of the boiler in such a way as that its bottom shall not be subjected to the direct action of the heat, and of introducing it laterally among the vertical tubes, we not only allow of the depositing of the sediment as stated, but cause a decided and rapid circulation, preventing all incrustation on the interior of the tubes, and augmenting the generation of steam. To clean out any ashes that may accumulate around the lower ends of the tubes, an opening, closed in the manner of a man-hole, must be prepared, as at R, or in any other convenient situation. S S S, Fig. 435 are the ordinary openings into the fire-chamber.

The improvements in this patent consist in arranging the fire-chamber or furnace of a tubular boiler at the side, so that the heat shall act on the upper half of the tubes, in combination with a diaphragm or partition, and flue to carry off the flame, heated air, &c., to act on the lower half of the tubes after acting on the upper half, as herein described.

The patentee also claims the making of the bottom of the boiler of a conical or dished form, with a mud or blow-off valve in the lowest part of the concavity, in combination with the vertical tubes communicating with the bottom in the manner herein described, to permit the deposit of the sediment, there being a water space surrounding them to induce a circulation of the water up the tubes and down the surrounding water space, to wash the sediment towards the mud or blow-off valve, as herein described.

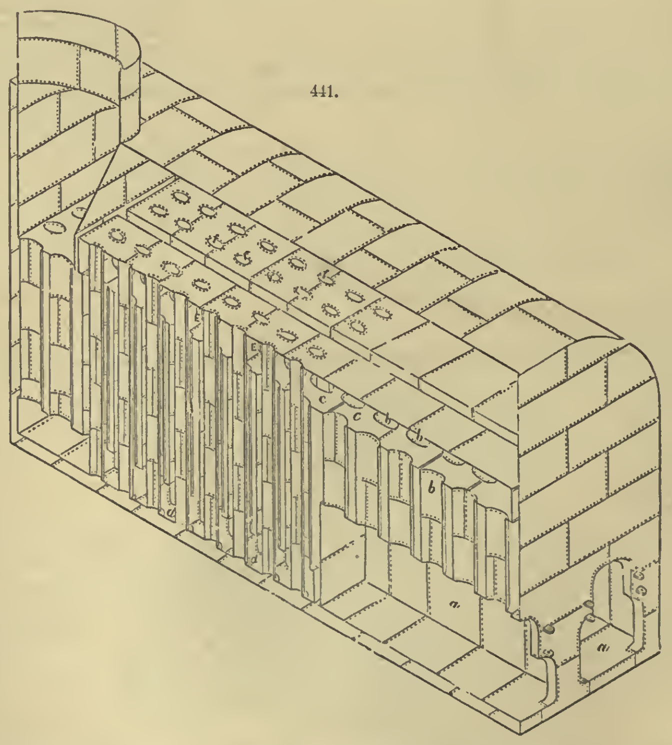
Steamship Osprey's boilers.—These boilers, represented in Figs. 436, 437, and 438, were built early in the spring of 1850, and are the same, in general arrangement, as that of the Earl of Dundonald.

A A, fire-doors; B B, ash-pits; C C, furnaces; D, vertical tubes; E, flue, in all the figures.

Boilers of the steam-ships Atlantic, Pacific, Baltic, and Arctic—Figs. 439 and 440.—The only difference between these boilers and those of Dundonald is in the furnaces, which are here double, one being above the other, caused by the necessity of obtaining more grate surface than could be obtained with one range of furnaces, the objection that had been urged against allowing the heat to act against the whole length of the tube having, by experiment, been found to be without cause.

A A, fire-doors; B B, ash-pits; C C, furnaces; D, vertical tubes; E, flue, in both figures

441.



Improved steam-boiler—By Wm. E. Milligan, New York City. Fig. 441 represents the boiler. The nature of this invention consists in a new arrangement of flues, tubes, and water spaces within a boiler for generating steam, whereby is presented a much enlarged amount of surface to the action of heat.

The construction is as follows: The general external appearance of this boiler is as of usual make, as is also the construction and arrangement of the furnace within it, but upon the upper side of the fire-place *a* is placed a series of flues *b*, of a number and capacity sufficient to carry off readily the products

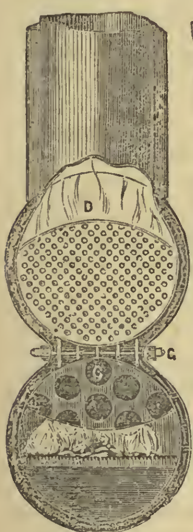
of combustion from the furnace. These flues open into a horizontal flue *c*, which is placed above the furnace and below the water line of the boiler. Back of the furnace *a*, and near to the bottom of the boiler, is another horizontal flue *d*, and between these horizontal flues is a series of vertical flues, similar to the flues *b*, but necessarily longer, as shown at E, and these flues are for the purpose of conveying the products of combustion from the upper to the lower horizontal flue. Through the centre of each of the vertical flues E is placed a tube *f*, of, say, one half the diameter of the flue, and these tubes extend from the upper tube-sheet of the horizontal flue *c*, through the lower tube-sheet of the flue *d*, as shown. The water passes through these tubes, and the purpose of them is to present greater surface for the absorption of heat, as well as to insure the circulation of the water within the boiler. From the lower horizontal flue *d*, the product of combustion is either conveyed directly into the chimney, or it may be returned to another upper flue *c'*, through the flues E'; thence again to another lower flue *d'*, through the flue E''; and thence into the chimney by means of the flues *b'*, as shown; one, two, or more furnaces arranged with flues and tubes thus constructed, may be placed within the same shell, sufficient space being left between them, as shown, for the circulation of the water.

The practical operation is this: The water in the boiler rising above the upper horizontal flue fills the tubes *f*, and surrounds all the flues. The product of combustion passes from the flue *c* through the vertical flues E, parting with its heat on the one side to the water surrounding those, and on the other to the water within the tubes *f*. The water contained in the tubes is much more rapidly heated than that surrounding the flues, as its volume is less, and hence by known laws a regular and perfect circulation takes place within the boiler.

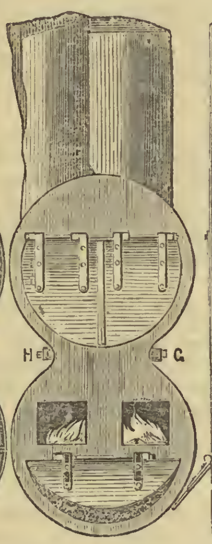
The patentee does not mean or intend to limit himself to the precise form of construction herein set forth, as it is obvious that if desirable the flues *c* and *d* may be placed vertically, and the others may be horizontal.

What the patentee claims as his own invention is the general arrangement of the tubes and flues of the boiler in the manner described; that is to say, the water tubes connected with an upper and lower tube-sheet, in combination with the flues of less length than the tubes, which flues are also connected with an upper and lower flue-sheet, whereby two horizontal flues are formed in such connection with each other by means of the vertical flues, that the product of combustion from the fireplace shall pass into the upper horizontal flue, and thence down the vertical flues into the lower horizontal flue, having thus the facility of parting with its heat on the one hand by radiation through the flues to the water spaces surrounding them, and on the other through the tubes to the water circulating through those; and this whether the said tubes and flues are placed vertically or horizontally

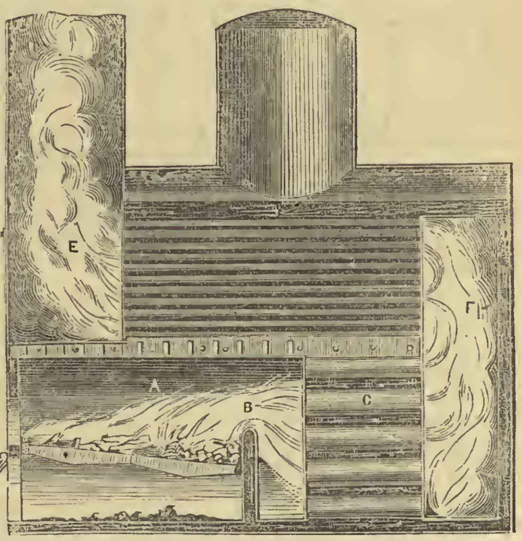
A. 442.



B. 443.



C. 444.



Boiler invented by E. A. Bourry. Figs. 442, 443, 444.

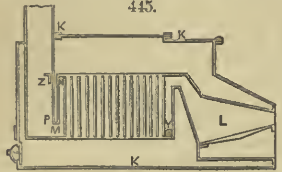
The aim of the inventor of this boiler has not been, like with many others, to obtain an incredible saving of fuel, but to insure great safety, combined with restriction of space and cost.

The cylindrical form of boilers is the best adapted for high-pressure steam: and the smaller the diameter, the more the boiler will be able to stand. Boilers of small diameter have been in use these many years with great success, for the working of stationary engines, but on board of vessels they are scarcely applicable, because—1st, Boilers are required with internal fire; 2d, such boilers must be in great number, which occasions a very awkward disposition and management; and, 3d, a given quantity of fuel is burned more economically on one large grate, than on several small ones, as with the former it requires less draught, and the combustion is more complete.

Now, to combine a boiler of a small diameter, with a large heating and grate surface and internal fire, seems at the first sight to be next to impossible, and yet this boiler embraces all those qualities.

A is a cross-section through the fire and smoke box; B is a front view; and C is a longitudinal section, showing the whole internal arrangement. The boiler consists of two cylindrical parts, placed above each other: the lower part contains the fire-box, bridge-wall, and main-flues; the upper one contains the return-flues, smoke-box, and steam-room. If space or convenience require it, the boiler may be made much shorter, in dispensing with the main-flues, in which case the return-flues can be made of a smaller diameter. It will be seen in the drawing, that the two cylinders are not entire, but are as if a slit was cut out on each of them, all the way along, and both joined there together, which leaves a free passage to both water and steam. But as, at the junction of both cylinders, the boiler would have a tendency to open outwards, this is prevented by a strong iron bar being placed in each hollow, and both kept securely together by a number of traversing bolts *a*.

445.



The boilers of the Atlantic and Pacific, of the Collins line of ocean steamers, are designed from that of Lord Dundonald, patented in England, Jan. 19, 1843, a longitudinal section of which is here shown, (Fig. 445.)

The earl says, "This figure shows a section of apparatus for generating steam for steam engines, constructed according to this part of my invention, and the apparatus is composed partly of tubes or hollow surfaces, the interior of which are open to the water spaces of the boiler, with which the tubes are combined. Such boiler or outer vessel may be varied in shape so long as there be a chamber as hereafter described, between the furnace and the fire-place and the chimney. K K is a steam boiler, which may be of a square or cylindrical section, or other convenient figure; L is the fire-place, M M M M is a rectangular chamber, there being a number of tubes or hollow surfaces in the upright position, through which the water flows in consequence of the water therein becoming hotter than other parts of the boiler. The heat of the fire passes into the chamber M at N, over the bridge O, at the end of the furnace or fire-place; and the passage P, from the chamber M into the flue or chimney, is situated as low as possible, in order that the greater heat of the vapors may be retained in the chamber M M, for it will be readily understood that the more highly heated vapors or products of combustion will occupy the upper part of the chamber M M, and the draught into the chimney will only carry off the cooler parts of the vapors, the more highly heated being comparatively in a quiescent state, at the upper part of the chamber M; and it is the peculiar arrangement of the chamber M within a steam boiler, when containing tubes or hollow surfaces, and combined with the outlet P into the chimney, so as to leave a considerable space above it (for the more highly heated vapors to be retained in the chamber M), which constitutes the peculiar character of my invention. Z is an opening into the chimney at the upper part of the chamber M M, to facilitate the getting up of a draught when first lighting a fire, it being closed at all other times; Y is a steam pipe in connection with the upper part of the boiler, having a stop-cock; this pipe is drilled with many small holes in the direction towards the chimney, by which numerous jets of steam can be projected amongst the tubes, in order to sweep away the dust and ashes when required. I would remark that it is not necessary to have the tubes in an upright position."

Such is the Earl of Dundonald's account of his invention. This boiler is superior to all that have preceded it, and is *identical* with those now in use on board the steamer Osprey, with the exception that her boilers have not the opening Z, or the steam pipe Y, both of which would be an improvement.

In December, 1845, Jas. Montgomery took out his patent for a tubular boiler, of which a description has already been given, the distinguishing feature of which is a horizontal diaphragm placed about midway in the tubes. Several of these boilers were introduced into vessels of moderate size, and several were employed for stationary purposes, and effected a considerable saving of fuel when they had supplanted other boilers.

The success attending the Montgomery boiler in this country called the attention of those interested in marine navigation to them; and when the steamers Atlantic and Pacific were begun under the direction of Mr. E. K. Collins, of New York, he caused a large number of experiments to be made with vertical tubular boilers for use in salt water. The performance of the steamboat Jonas C. Heartt, with Montgomery's boiler, was carefully noted for several days, being equal in time to a trip to Europe.

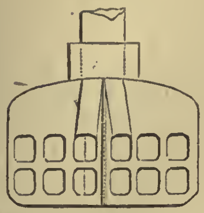
It being satisfactorily ascertained that the tubes would not choke up, but, on the contrary, would keep perfectly free from scale, Mr. Collins concluded to adopt some form of vertical tubular boiler, and determined to test the use of vertical tubular boilers—in fact, the boiler of Dundonald. After a series of experiments, proving that there was no objection, the boilers of the Atlantic and Pacific were designed by his chief engineer, John Farron, jr.

The only difference between these boilers and those of Dundonald is in the furnaces, which are here doubled, one being above the other, caused by the necessity of obtaining more grate surface than could be obtained with one range of furnaces, the objection that had been urged against allowing the heat to act against the whole length of the tube having, by experiment, been found to be without cause.

Tubular boilers have suffered much in reputation by being made too contracted in the water-ways, the tubes too close together, and the plates not sufficiently strong to resist the increased pressure used in them. They save both in weight and space, and are now designed quite free from the general objections made to them; they are not more expensive in fuel when a due proportion exists between the absorbent surface and the surface of the grates; and there is no reason why they should not be as durable as the ordinary flue boiler; they perhaps require more attention in blowing off, and keeping free from salt and earthy incrustations.

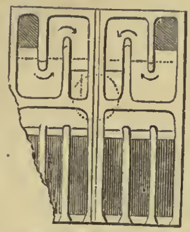
English Marine Boilers.—Figs. 446, 447, 448 and 449 are different views of the boilers of the steamer Phœnix, a steamer constructed by Messrs. Scott, Sinclair & Co., for plying between Capetown and Algoa Bay, at the Cape of Good Hope. This vessel was provided with collecting vessels within the boiler for obviating the deposition of scale.

446.



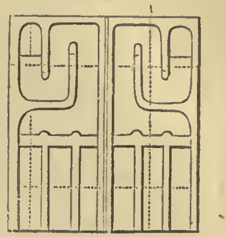
SCALE.—1-16th inch = 1 foot.

447.



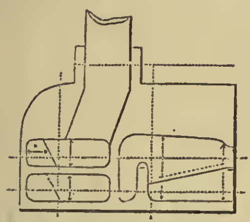
SCALE.—1-16th inch = 1 foot.

448.



SCALE.—1-16th inch = 1 foot.

449.



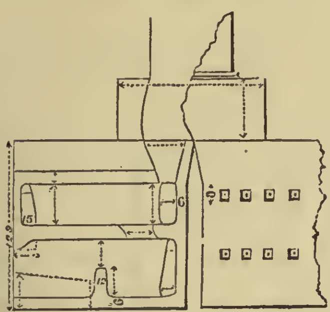
SCALE.—1-16th inch = 1 foot.
Longitudinal Section.

450.

SCALE.—1-16th inch = 1 foot.
Elevation and Transverse Section.

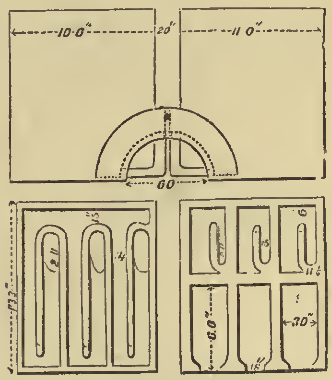
Figs. 450, 451, and 452 represent the boilers of the Achilles steamer, constructed by Messrs. Caird & Co. This vessel plies between Liverpool and Glasgow, and is well known for her numerous excellencies.

451.



SCALE.—1-16th inch = 1 foot.
Longitudinal Section and Exterior.

452.

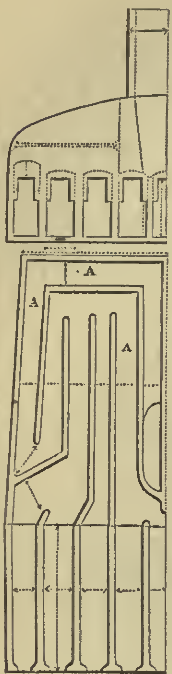


SCALE.—1-16th inch = 1 foot.
Horizontal Sections and Bird's-Eye View.

Fig. 453 represents the boilers of the sister ship, the Eagle, also by the same makers. There is nothing of peculiar excellence in these plans; and, for steam vessels, we believe boilers of this kind will be superseded by the tubular plan of boiler, of which we shall give all the best specimens. But a good number of boilers upon the common flue plan are still made, so that some specimens of them are indispensable; and, indeed, there are still far more flue-boilers in use than there are of any other description. In most of these boilers it is a fault that the furnaces are made too long and narrow, and the consequence is, that it is impossible to fire them on a long sea-voyage, especially in stormy weather. It is much preferable to restrict the furnaces to a moderate length, and give the bars a considerable elevation, so that they may always be well covered with coal at the after ends. When the furnaces are very long, a good deal of air generally escapes into the flues at the after end of the bars, the effect of which is materially to lessen the generation of steam.

Figs. 454, 455, and 456 represent the boilers of the Thames and Medway, two vessels of large size, constructed by Messrs. Maudslay & Field for the Mail Steam Packet Company. The boilers of these vessels have been very successful, and are among the best specimens of the flue-boiler as applicable to

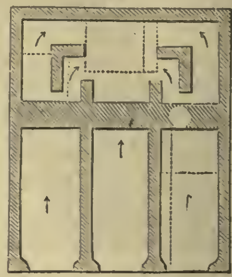
453.



Scale.—3-20th inch = 2 feet.—Elevation and Horizontal Section.

marine engines hitherto produced. We do not know of any boiler of this kind that engineers may imitate with greater safety, as regards their power of generating steam, though there are many specimens distinguished by a greater durability. In some of the boilers recently introduced in the Mail Steamers, the furnaces stand athwartships, and the plan is attended with the material advantage that the coals trim more easily; for the coal reserve in this arrangement situated behind the boilers, and another depot standing between the boilers and the engines, communicate immediately with the stoke-holes, whereby an easy transfer of the coal becomes accomplishable.

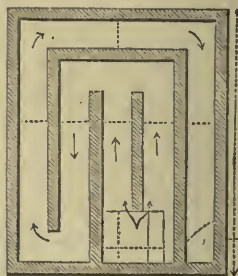
454.



Horizontal Section through Flues.

Figs. 457 and 458 are also views of the boilers of the Thames and Medway. These views are perpendicular sections through the lines A B and C D, shown in the horizontal section through the furnaces, and the horizontal section through the flues. The dotted sweeps at the two upper corners represent the ascent of the flue into the funnel. The flue narrows in width and rises in height as it approaches the chimney, for the same area is not required for the transmission of the smoke after its volume has been contracted by the communication of heat to the water, and a less depth of water above the flue suffices after the heat of the smoke traversing it has been well-nigh expended. The bridges are water bridges, and their superior ridges do not run in a horizontal, but in an oblique direction, the design of which is to facilitate the extrication of the steam. There are four boilers in all, and the boilers are fired from both ends.

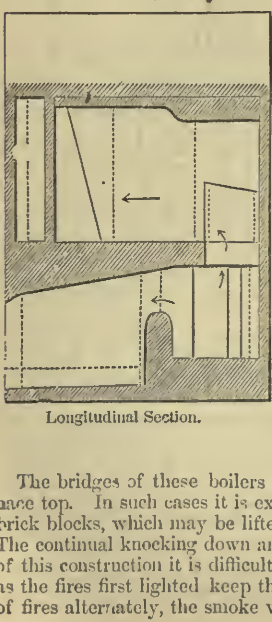
455.



Horizontal Section through Furnaces.

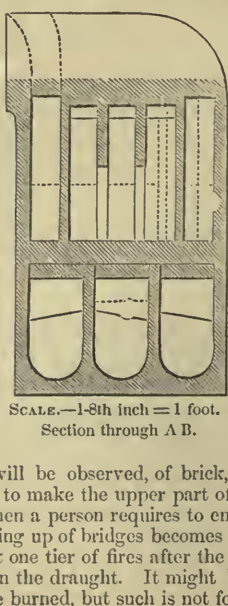
In furnaces with two lengths of furnace-bars, it is a good plan to make the centre-bearer double, so that the ends of the bars may have a space between them through which the ashes will be precipitated; the space thus left enables the bars to expand without injury on the application of heat, whereas, without some such provision, the bars are very liable to get burned out by their centres bending up into the furnace, or else the lugs which carry the bearer-bars will be perpetually being carried away. A similar space should be left between the fore end of the bars and the dead plate at the furnace mouth, and care should be taken that not only the ends of the bars do not touch, but that the heels of the bars do not rest against the furnace-bearers.

456.



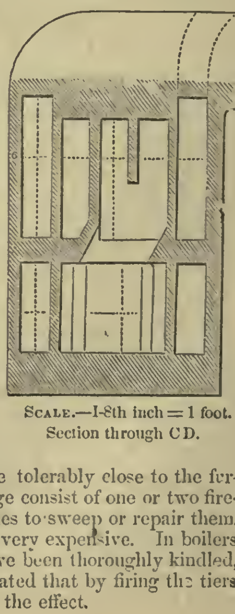
Longitudinal Section.

457.



Scale.—1-8th inch = 1 foot.
Section through A B.

458.



Scale.—1-8th inch = 1 foot.
Section through C D.

The bridges of these boilers are, it will be observed, of brick, and come tolerably close to the furnace top. In such cases it is expedient to make the upper part of the bridge consist of one or two fire-brick blocks, which may be lifted off when a person requires to enter the flues to sweep or repair them. The continual knocking down and building up of bridges becomes otherwise very expensive. In boilers of this construction it is difficult to light one tier of fires after the others have been thoroughly kindled, as the fires first lighted keep the lead in the draught. It might be anticipated that by firing the tiers of fires alternately, the smoke would be burned, but such is not found to be the effect.

Provision has been made in these boilers for the introduction of a fan-blast, which would at once cure the evil of a defective draught. The furnaces would, in this plan, be made close, and the blast would be introduced into a chamber at the back of the ashpit A, Fig. 461, from whence it would pass into the ashpits by necks A A A, Fig. 459. One inconvenience, however, of a fan-blast thus applied is, that the smoke comes out of the furnace-doors very much when they are opened.

Almost every engineer has made tubular boilers that were short of steam, but we never before met with one who acknowledged it.

The original boilers of the Great Western contained of flue surface 2950 square feet, and of furnace surface 890 square feet, making 3840 square feet of heating surface; area of fire-grate 202 square feet; capacity of steam-room 1150 cubic feet; weight of boilers and steam-pipes 202 tons; weight of water 80 tons; average consumption of coal 1000 tons per voyage, out and home, of 27 or 28 days. In the tubular boilers, Figs. 459 to 461 the tube surface is 5900 square feet, smoke-box surface 830 square feet; furnaces 420 square feet; making 7150 square feet of heating surface; area of fire-grate 145 square feet; weight of boilers 56 tons; weight of water 52 tons; capacity of steam-room 1320 cubic feet; average consumption of coal per voyage out and home, of 29 days, 696 tons. The speed of the vessel, it will be observed, has somewhat declined with the new boilers, but there is a greater economy in fuel upon the same distance. The horse power of the Great Western is about 400; the particulars of the two boilers will therefore stand as follows:—

	Old Boiler.	New Boiler.
Heating surface per horse power	9·6	17·875
Fire-grate per horse power	·5	·3625
Steam-room per horse power	2·875	3·3
Coal per hour per horse power	8·333	5·6

The consumption of fuel, as here set down, it must be borne in mind is that of the old boiler in its super annuated state, and of the new boiler in its best state. The old boiler, when new, did not consume more than 6 lbs. of coal per horse power per hour.

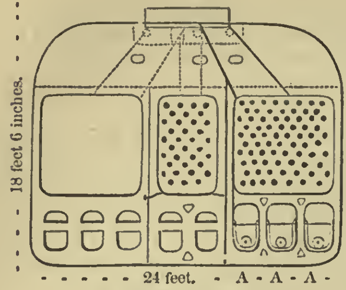
The tubes of these tubular boilers are of iron of 3 inches internal diameter, and 8 feet in length. The furnaces are 8 feet 3 inches in length, which is, in our judgment, a greater length than can be fired effectually on so long a voyage as the Great Western has to perform. The water within the boiler rises some distance above the top tubes. It would be better, we think, to let the return tubes go through the steam, which would dry it very effectually, and surcharge it in some degree with heat. This could easily be done by lowering the water-level, and the hot air will be sufficiently cooled, after passing through the lower tier of tubes, to prevent any injury to the upper tier from an excess of heat. One of the advantages of iron tubes is, that they can be subjected to a degree of heat, with impunity, that would be unsafe to apply in the case of brass tubes. It is said, however, that the scale adheres to them with greater tenacity than to brass, but this objection is not likely to prove of much weight if the boilers be well blown out, for in that case very little scale will be formed at all.

Figs. 462 and 463 represent the boilers of the British Queen steamer, constructed to ply between London and New York. There is nothing very peculiar in this kind of boiler; and, indeed, it is nothing more than the common marine boiler, as used for the ordinary coasting vessels, constructed upon a larger scale. There are four boilers in the vessel, ranging athwartships, containing in all fourteen furnaces, the wing boilers containing four furnaces each, and the midship boilers three furnaces each. The projection of the water-space into the flues at the after-end of the wing boiler is to obviate a back-draught in the furnaces, in consequence of the currents of hot air meeting one another in a direct antagonism at the point where they coalesce, and which they would do but for this protuberance, which deflects each of them sufficiently to make it enter, without conflict, the longitudinal flue. These boilers were kept supplied with fresh water, as the engines are fitted with Hall's condensers, which return the condensed steam to the boiler to maintain the water-level. This species of condenser is now discontinued in most vessels, as its weight and expense are formidable objections, and it does not act as a preservative of the iron of the boiler from corrosion. One government vessel, some time since, fitted with Hall's condenser, had no less than 22 miles of copper pipe for accomplishing the condensation of the steam. The use of salt water in boilers is attended with very little inconvenience if they be often blown out, and their durability is little, if at all, increased by the employment of fresh water.

Figs. 464 and 465 represent the boilers of the City of London steamer, a vessel lately constructed by Mr. Napier, of Glasgow, to ply between Aberdeen and London. These boilers are much upon the plan of the boilers of the Thames and Medway, and are fired from both ends instead of from one end, as in the boilers of the British Queen. There is a hanging water-bridge, it will be observed, at the end of the furnace, Fig. 464, beneath which the flame has to descend before it can enter the flues. This arrangement we look upon as very judicious. The hot air, by virtue of its specific levity, ascends into the upper part of the furnace-chamber, where it remains until it has given out a considerable portion of its heat, and it is only after its specific gravity has been increased by the extraction of heat that it can overflow into the flues. It is also a good practice to place a hanging bridge of sheet-iron at the after-end of the flue, where it enters the chimney.

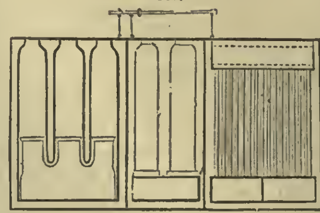
Figs. 466, 467, and 468, represent the original boilers of the steamer Tagus, constructed by Messrs. Scott, Sinclair & Co. The following are some of the dimensions of the original boilers:—Length 24 feet 3 inches, height 10 feet; breadth of each boiler 7 feet 6 inches, making the total breadth of the boilers about 22 feet 8 inches, with projections of rivet-heads. Length of under furnaces 8 feet; length of upper furnaces 7 feet 6 inches. Breadth of furnaces 3 feet; total number of furnaces 12. Each boiler contains 14 iron pipes of about 10 inches in diameter, and 10 feet in length, through which the smoke passes on its way to the chimney. These pipes are formed of boiler-plate, with turned rings or collars attached to each end, which are inserted into holes in the smoke-box plates, and then riveted over. These rivets are liable to get burned away by the action of the flame, as the collars within pre

459



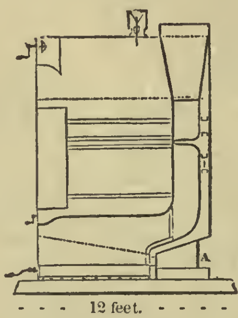
Scale.—9-128th inch = 1 foot.
Transverse Section.

460.



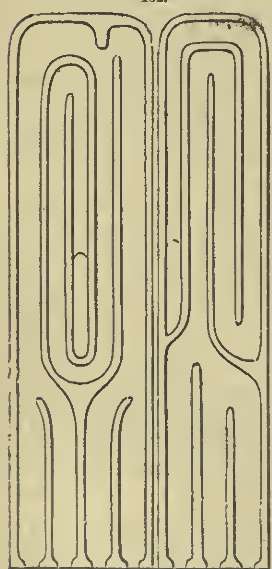
Scale.—9-128th inch = 1 foot.
a. Horizontal Section through Furnaces.
b. Horizontal Section above Furnaces.
c. Horizontal Section above Tubes

461.



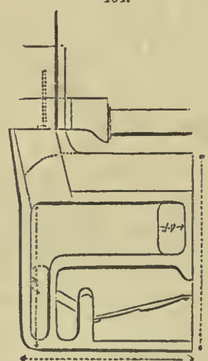
Scale.—9-128th inch = 1 foot.
Longitudinal Section.

462.



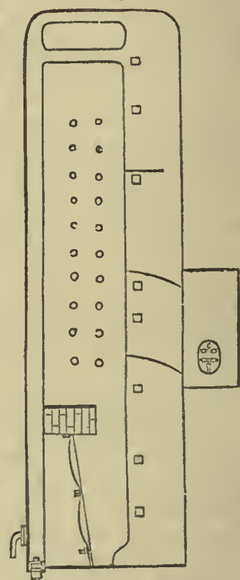
Horizontal Section.

464.



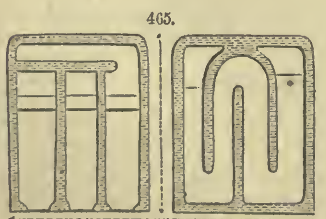
Scale.—·075 inch = 1 foot.
Perpendicular Section.

463.



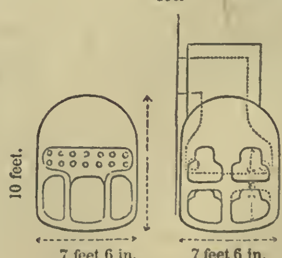
Longitudinal Section.

465.



Scale.—·075 inch = 1 foot.
through Flues. Horizontal Section. Through Furnaces

466.

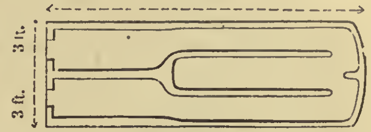


Scale.—9-128th inch = 1 foot.
Transverse Section. Elevation.

vents the water from getting across to the angle, and the plates into which they are fixed then get pressed out by the force of the steam. It would be a good plan to cover these rivets with another perforated plate placed above them, the holes in which should be of a somewhat smaller diameter than that of the tubes.

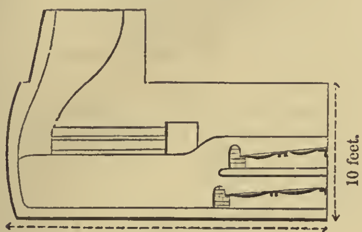
Figs. 469, 470, 471, 472, 473, and 474, represent the boilers of the Queen steamer, a river vessel, constructed by Messrs Rennie, and well known for her swiftness and efficiency. The object this boiler

468.



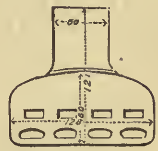
24 feet 3 inches.
SCALE.—9-128th inch = 1 foot.
Horizontal Section.

467.



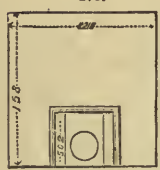
24 feet 3 inches.
SCALE.—9-128th inch = 1 foot.
Longitudinal Section.

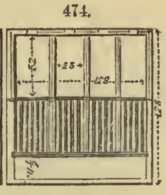
469. 470.



SCALE.—1-16th inch = 1 foot.
Transverse Section. Elevation.

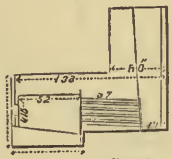
473. 474.

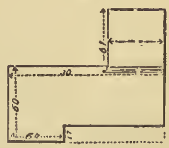




SCALE.—1-16th inch = 1 foot.
Plan. Horizontal Section.

471. 472.





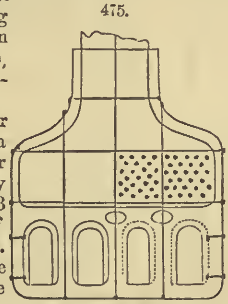
SCALE.—1-16th inch = 1 foot.
Longitudinal Section. Elevation.

seeks to attain is lightness, and it is therefore made so as to hold very little water. It does not, however, appear to be well calculated to sustain any considerable pressure, though this is an object of importance in vessels intended to go fast. The following are some of the principal dimensions:—Length 13′ 8″; breadth 12′ 8″; height 6′ 0″; length of furnaces 5′ 2″; length of tubes 5′ 7″; breadth of furnaces 2′ 8″; diameter of tubes 2′ 6″; material of tubes brass. Total number of tubes 228. Diameter of cylinder of engines 29′ 3″; length of stroke 4′ 6″. There are two engines on the direct action plan. Collective power 76 horses.

If any considerable pressure of steam be employed in this boiler, it will be necessary to stay down the boiler top very firmly, both to the tops of the furnaces and the bottom of the boiler; for the force acting against the boiler-top, and tending to raise it upwards, will be immense, if a high pressure be adopted. To stay the boiler-top to the tops of the furnaces alone would not be sufficient, for the tops of the furnaces might alter their form, and the stays would then be of very little avail. The stays to the bottom of the boiler, however, if carried in the usual way, would have to be attached to the bottoms of the water spaces, and there they would be much in the way when the boilers are being cleaned. Indeed, it would be almost impossible to clean out the water legs effectually with stays so situated. and the best method, therefore, appears to be either to stay the boiler-top to a strong inverted arch spanning the water spaces, or to place a succession of iron arches over the furnace tops, to keep them in shape, after the fashion practised in Stephenson's locomotives, and to stay the boiler-top to these.

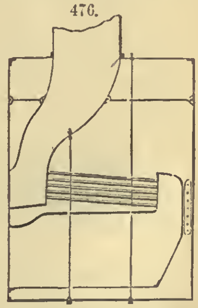
Figs. 475 and 476 represent a small tubular boiler constructed by Messrs. Horton & Son for a coasting steamer called the Zephyr. This boiler has been found to perform well, and is, in every respect, satisfactory. The tubes are of iron, 3 inches in diameter, and 6 feet long. Length of furnace, 6 feet; number of tubes, 168. 2 engines. Consumption of coal per hour, about 6 cwt. The pressure of steam is about 5 lbs. on the square inch.

475.



SCALE.—1-10th inch=1 foot.
Front View and Transverse Section.

476.



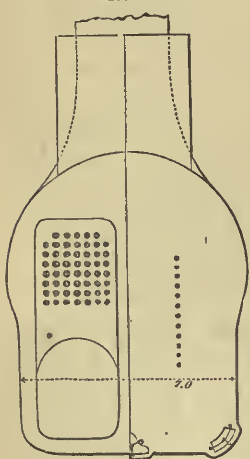
SCALE.—1-10th inch=1 foot.
Longitudinal Section.

Figs. 477 478, and 479, represent a boiler, by Messrs. Miller, Ravenhill & Co., of the tubular

kind. It has been found expedient to introduce a jet of steam into the chimney of this vessel to quicken the draught. The tubes are of brass, $3\frac{1}{4}$ inches in diameter, and the tube-plates are of iron. A galvanic action between the brass and the iron has been found to arise in some boilers, which shows itself, not at the ends of the tubes, but at the ends of the athwartship stays which bind the sides of the boilers together; and the iron plate around these stays very soon acquires the appearance of having been scooped out by a knife; but in other boilers no action of this kind has been found to take place, and it has been doubted whether a leakage caused by the inadequate fastening of the stays has not had something to do with its production. The evil would probably be obviated by the application of a washer of zinc. Experience in the use of tubular boilers certainly shows that brass tubes are on the whole the most eligible. Iron tubes are speedily eaten into holes by corrosion, and it is remarkable that the corrosion chiefly takes place upon the under side. Brass tubes, on the contrary, are found to last many years. It appears to be the best plan to refrain from attempts at scaling brass tubes, but they may be withdrawn once a year, cleaned, and reinserted.

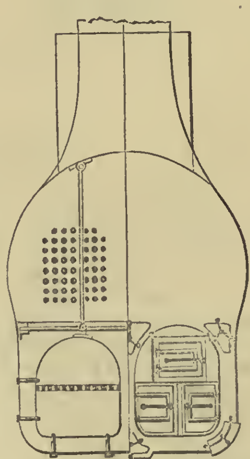
Figs. 480, 481, and 482, represent the boilers of the steam vessel Ocean. The tubes of these boilers are of iron, $3\frac{1}{4}$ inches in diameter, and 9 feet long; furnaces 7 feet long, and 2′ 1″ wide. There are three boilers in all: the centre one with three furnaces, and the two wing ones with two furnaces each. Total breadth of boilers $19\frac{1}{2}$ feet; total length 14 feet; total number of tubes, 378; two engines—diameter of cylinder, 56 inches; length of stroke, $5\frac{1}{2}$ feet; pressure of steam about $4\frac{1}{2}$ lbs.; consumption of coal about 18 cwt per hour. In ordinary coasting vessels the plan of firing from each end is objectionable, as the length in the vessel occupied by an additional firing space is a manifest waste of room; and there will be no difficulty in short voyages, about maintaining the trim of the ship on account of the stowage of so evanescent a cargo as coal in the wake of the furnaces.

477.



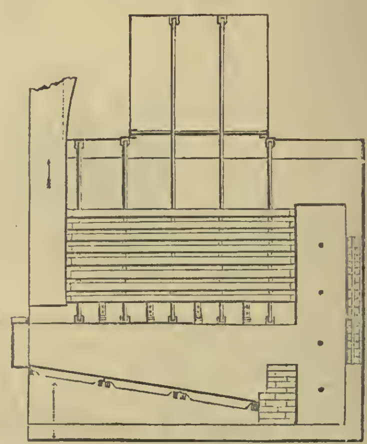
SCALE.—3-20th inch = 1 foot.
Front View one-half in Section.

478.



SCALE.—3-20th inch = 1 foot.
Back View one-half in Section.

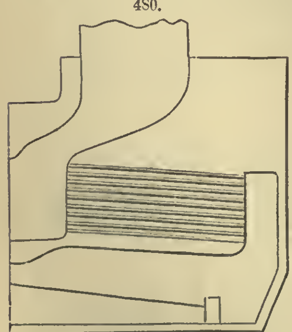
479.



11 feet.

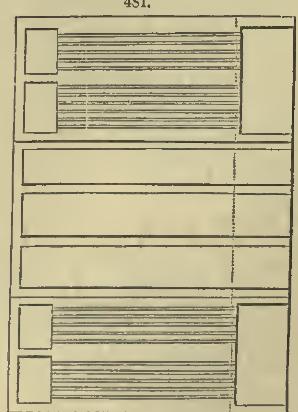
SCALE.—3-20th inch = 1 foot.
Perpendicular Section.

480.



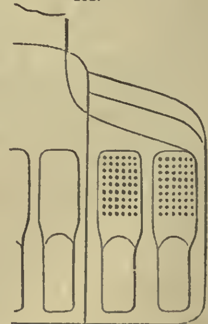
SCALE.—3-28th inch = 1 foot.
Longitudinal Section.

481.



SCALE.—3-28th inch = 1 foot.
Horizontal Section through Tubes of Wing Boilers and Furnaces of Centre Boiler.

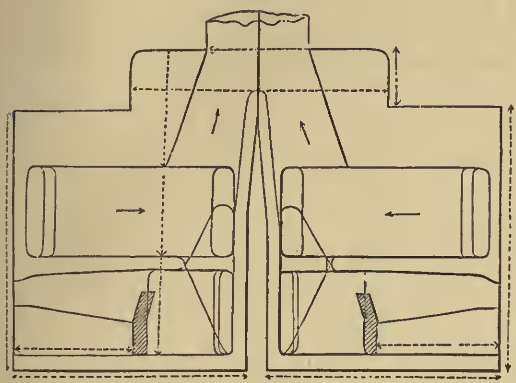
482.



SCALE.—3-28th inch = 1 foot.
Transverse Section.

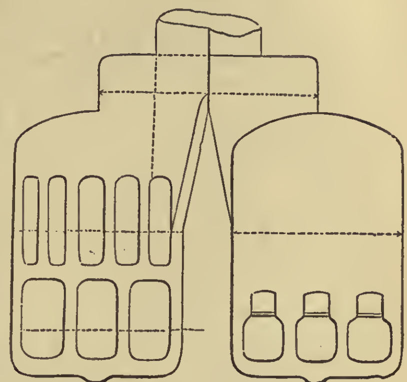
Figs. 483, 484, and 485, are different views of the boilers of the steamer Forth, belonging to the English Mail Steam-Packet Company. These boilers are well worthy of the attention of the engineer, as they have approved themselves more economical than any of the other boilers employed in those vessels, at the same time that there is an abundance of steam, and the speed of the vessel is well maintained. The following are some of the more important particulars: There are four

484.



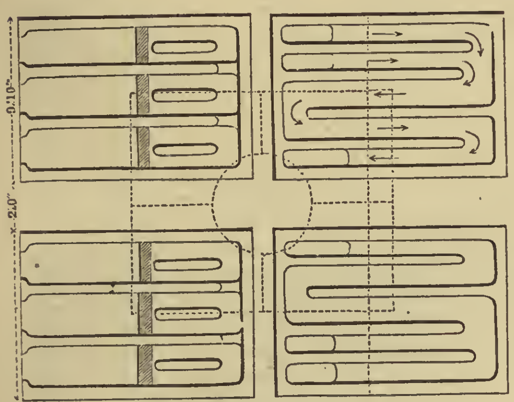
Scale.—1-11th inch = 1 foot.
Longitudinal Sections.

483



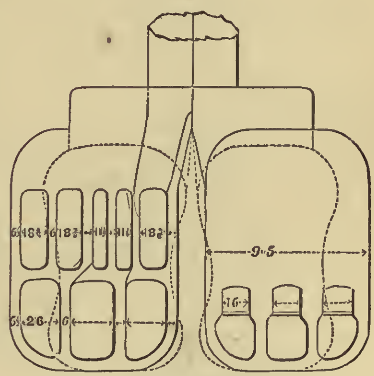
Scale.—1-11th inch = 1 foot.
Transverse Section. Front View.

485.



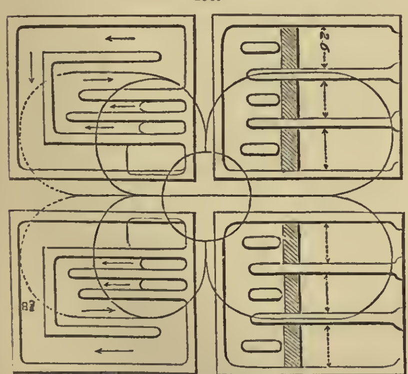
Scale.—1-11th inch = 1 foot.
Horizontal Section through Furnaces. Horizontal Section through Flues.

486.



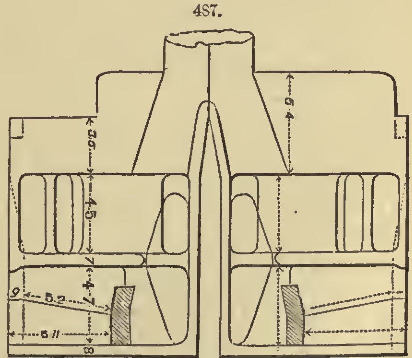
Scale.—1-11th inch = 1 foot.
Transverse Section. Elevation.

488.



Scale.—1-11th inch = 1 foot.
Horizon Section through Furnaces. Horizontal Section through Flues.

487.

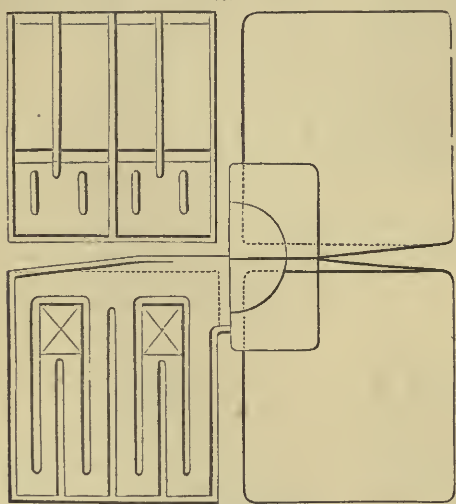


Scale.—1-11th inch = 1 foot.
Transverse Sections.

boilers, with three furnaces in each, making 12 furnaces in all. Length of each boiler, 13′ 6″; breadth, 9′ 10″; height, 14′ 11″. There is a fore-and aft passage between the boilers, 2 feet wide, and an athwart passage 18 inches wide. Length of furnace, 7′ 4″; breadth of furnace, 31⅝ inches; diameter of chimney, 67 inches; height of flues, 5 feet.

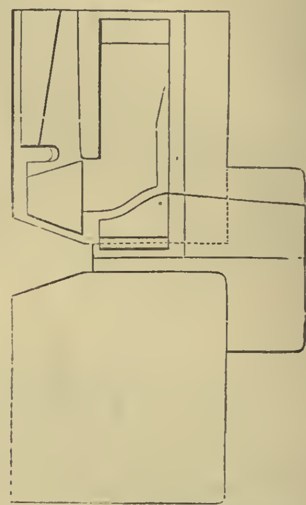
Figs. 486, 487, and 488, represent two sets of boilers constructed by Messrs. Bury, Curtis & Kennedy, for the two steam vessels Wladimir and Der Greuss Adler, the one belonging to the Russian and the other to the Prussian government, and both of the power of 320 horses: the boilers for the Russian vessel being of the tubular variety, while those for the Prussian vessel are on the common flue plan. The shape and dimensions of the tubular boiler are shown in the figures by means of dotted lines; and a just conception may thus be arrived at of the amount of space occupied by a tubular and a flue boiler of the same efficacy in raising steam.

489.



Scale.—1-8th inch = 1 foot.
a. Horizontal Section through Furnaces.
b. Horizontal Section through Flues.

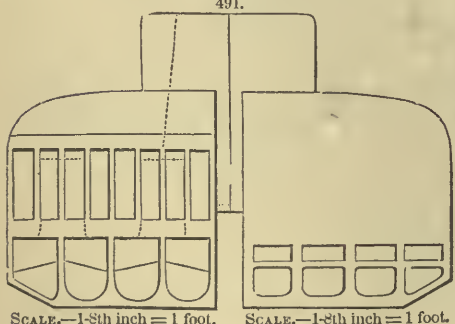
490.



Scale.—1-8th inch = 1 foot.
a. Side View.
b. Longitudinal Section.

Figs. 489, 490, and 491, represent the boilers of the Retribution, a steamer of 800-horse power; the engines being on the double cylinder plan of Messrs Maudslay. There is nothing very peculiar in these boilers, except their size; in other respects they very much resemble the boilers of the Great Western, and of the Thames and Medway, also by Messrs. Maudslay & Field, of which we have already given delineations.

491.



Scale.—1-8th inch = 1 foot. Transverse Section. Scale.—1-8th inch = 1 foot. Elevation

Miscellaneous observations on the construction and proportion of boilers, and the accidents to which they are liable.

The water-spaces.—The water-spaces between the furnaces should not be less than 5 to 6 inches wide, and between the flues 4 to 5 inches. The bottom water-spaces should be 8 inches, for the convenience of cleaning. It is usual to allow a space of 1 inch between the tubes of a tubular boiler, and these are best arranged in perpendicular rows, one over the other, by which means the steam escapes from their surface more readily than when arranged zig-zag. When water-bridges are used, they should not be less than 10 to 12 inches wide, and their tops should incline about 3 inches to the foot, to allow of the steam escaping more readily from the interior surface.

Heating surface arranged to permit the easy escape of the steam—Care must be taken, in proportioning the boiler, that no part of the heating surface may be so situated that the steam will not readily escape from it to the surface of the water, as in such case the plate, being left in contact with steam in place of water, becomes intensely heated and destroyed, and an explosion is not an unfrequent result. It is found in practice that perpendicular heating surface, such as the sides of the rectangular flues in a flue boiler, is by no means so efficient for raising steam as an equal amount of horizontal surface, such as the tops of the same flues. The reason of this is sufficiently obvious; as the steam, in the first case, rising perpendicularly from each portion of the surface of the metal, forms a film or stratum of vapor in contact with the sides of the flue, thus preventing the free access of the water to the hot metal; but in the other case, the steam, leaving the iron as soon as generated, allows the water to be constantly in

contact with it. From the same cause, the flat bottom of an internal metal flue is very inefficient as heating surface; and it is also found that plates which are liable to be exposed in this manner to imperfect contact with the water, either as side or bottom surface, are subject to a much quicker wear than the tops of the flues of the same boilers.

Strength of boilers.—1st. To know the force which tends to burst a cylindrical vessel crossways, or, in other words, to separate the *head* from the curved *sides*, we have only to consider the actual area of the head, and to multiply the units of *surface* by the number of units of *force* applied to each superficial unit. This will give the total *divellent* force in that direction.

2d. The amount of force which would tend to divide the cylinder in halves lengthways, by separating it along two lines on opposite sides, would be represented by multiplying the diameter by the force exerted on each unit of surface, and this product by the length of the cylinder. But even without regarding the length, we may consider the force requisite to rupture a *single band* in the direction now supposed, and of one lineal unit in breadth; since it obviously makes no difference whether the cylinder be long or short, in respect to the ease or difficulty of separating the sides. The *divellent* force in this direction is truly represented by the diameter multiplied by the pressure per unit of surface. *Hence, the thickness of the plates of cylindrical boilers should be in proportion to their diameters.* Ordinary boiler-plates will not bear more than 23 tons to the square inch; and as nearly one-third of the material is punched out for the reception of rivets, we must still further reduce the strength, and take 15 tons, or about 34,000 lbs. on the square inch, as the tenacity of the material, or the pressure at which a boiler would burst.

Strength of the plates.—A practical limit is imposed to increasing the thickness of the plates of an iron boiler, by the defective conducting power of the material; and it not unfrequently happens that boilers are weakened and destroyed by the very means adopted for securing additional strength, viz., by giving an injudicious thickness to those plates exposed to the greatest heat.

It is now generally understood that if the plates of the furnaces are made thicker than about $\frac{3}{8}$ of an inch, they are liable to be warped and "burnt" by the action of the flame, in consequence of the conducting power of the metal being insufficient to transmit the heat of the flame through the plate with such rapidity as to prevent the exposed side of the plate being softened and weakened by the intense heat, even although the other side of the plate may be in perfect contact with the water. From this cause, lapped joints, or rows of rivet-heads, should be avoided as much as possible in parts of the boiler exposed to *flame*, which is much hotter than *radiated heat.* The best position for the joints of the plates in the fire-boxes is in a slanting line, just below the fire-bars, in the ash-pit; and the plates for this part should be made as large as it is possible to have them rolled sound.

The usual thickness of iron plates for boilers is as follows: for fire-boxes, $\frac{3}{8}$ in.; flues, sides and tops, $\frac{5}{16}$ (the tops are sometimes $\frac{1}{4}$ in.); bottoms, $\frac{3}{8}$, and sometimes $\frac{7}{16}$ in. Outside shell of boiler, $\frac{3}{8}$ in. throughout, although the bottom is sometimes made $\frac{7}{16}$ in.; the up-takes to the bottom of the funnel should be $\frac{3}{8}$ in. The tube plates in tubular boilers are made from $\frac{1}{2}$ to $\frac{5}{8}$ in., charcoal iron. The funnel may be made with $\frac{1}{4}$ in. plate round the bottom, then $\frac{3}{16}$ in. and $\frac{1}{8}$ in. at the top. It should be divided by plates at the bottom, for 6 or 8 feet, into as many divisions as there are distinct boilers led into it.

Construction of boilers.—The whole of the shells of boilers intended to withstand any considerable pressure, should be double riveted, with rivets $2\frac{3}{8}$ inches from centre to centre, the weakening effect of double riveting being much less than that of single riveting. The furnaces above the line of the bars should be of the very best plates, three-eighths thick, and each furnace above the bars should consist of three plates, one for the top and one for each side, the underseam of the side plates being beneath the level of the furnace-bars. The tube plates of tubular boilers should be also of the best iron, $\frac{7}{8}$ to 1 inch thick; the shells should be of the best iron, and $\frac{7}{16}$ thick, at the least. Angle iron should not be used in any part of a boiler, as in the manufacture it becomes reedy, like wire, and is apt to split in the direction of its length. It is a much safer dependence to bend the plates, if it be carefully done, and without any more sharp turns than can be helped; but it is convenient to use a little angle iron about the furnace mouths, which should be of the very first quality. The whole of the plates of boilers should be punched with a double punch, one nipple of which enters the hole last punched, while the other punches the hole; and it is very convenient to have the punching-press provided with a travelling table, whereby the operation of punching and paring the edges of the plates is made a self-acting one. The use of drifts and screw-jacks in putting the parts of boilers together should not be permitted. The rivets should be of the best iron, $\frac{11}{16}$ in diameter. The whole of the work should be caulked both inside and outside, so far as it is accessible. It is very desirable that the space between the furnaces and tubes of tubular boilers should be sufficiently large to enable a man or boy to get in. The bend joining the top of the furnace at the after end with the bottom of the tube plate is very liable to get burnt away, and its repair will be most difficult, unless made accessible from the inside to hold on the rivets.

Division of the boilers.—In the case of engines of large power it is preferable to divide the boilers into several distinct pieces, each complete in itself, and capable of being used either in conjunction with the others or separately. This affords facilities for examining, repairing, if necessary, and cleaning the boilers in succession.

Staying and tubing of boilers.—It is usual to stay the flat portions of tubular boilers with about $1\frac{1}{8}$ inch round rods, from 16 to 18 inches apart each way, and flue boilers not quite so heavily. It is highly injurious to stay weak plates at long distances, as the alternate distension and contraction of the plate between the stays causes it to buckle round each stay every time that the pressure of steam is added or removed. This action, in time, wears a furrow round the fastening of the stay by throwing off the scale from the surface of the plate and opening the fibre of the iron, the circular piece of plate to which the stay-rod is attached remaining at the same time quite sound

By the English method, the tubes of boilers are most generally secured at the ends by means of ferules driven tight into them, the holes in the end plates being usually countersunk, and a corresponding projection being made on the ferules. The ferules next the furnace are best made of steel, while, for the other ends, malleable-iron ferules answer as well. The tool in which the ferules are made consists of three pieces; one piece is set in the anvil, and consists of a flat plate with a nipple on it, rising to half the depth of the ferule, and rounded at the corners; the next piece consists of a ring furnished with a handle, and with its lower edge recessed slightly into the flat plate so as to steady it, and this ring is larger in its internal diameter than the nipple by twice the thickness of the ferule; the last piece consists of another nipple made like the first, but formed with a head like a punch. A small hoop is formed by welding a piece of steel or iron, and is dropped into the space between the interior of the ring and the lower nipple; the upper nipple is then forced down by striking the punch-head with a forge-hammer, whereby the ferule is moulded to the right form; the parts are finally taken asunder, whereby the ferule is liberated.

In brass tubes the use of ferules appears to be indispensable, but in the case of stout iron tubes they are unnecessary; and the best plan, when iron tubes are used, appears to be to widen one end of the tube slightly, and to drive the tube in from the front of the boiler into both tube plates, the holes in the front plate being made one-sixteenth wider than those in the back plate, and the tube being widened correspondingly. Before the tubes are driven in, the holes in the tube plates must be slightly countersunk, and the tubes must finally be carefully riveted in. It will be expedient to screw a few of the tubes into the tube plates instead of riveting them, so as to serve as stays, and also as abutments to rivet the rest of the tubes against. The screwed tubes should be left a little longer than the others; and thin nuts made of boiler-plate should be screwed upon the projecting ends to prevent leakage, and add to the security of the staying. In fitting in the tubes in this way, great care is necessary to make them perfectly tight; and it will be expedient to turn the ends slightly in the lathe to give them a trifling taper, and make them all precisely of the same size. In driving them in, each tube should not be driven home at once, as that will spring out the iron between the holes; but they should be all fitted in first with the common chipping hammer, and when thus all equally fitted, they should be driven home by a heavy hammer, or ram. The countersink in the holes must be but slight, and must be filled rather by riveting up endways than by riveting over. In some cases boilers are made with collars riveted on the tubes immediately behind the tube plates, but this plan is attended with the objection that a tube cannot be renewed without taking the boiler asunder; and with the still greater defect, as it appears to us, that the ends of the tubes will be liable to get burned away in consequence of the internal collar preventing the access of the water. Boilers formed on this plan, therefore, will, we believe, be found to become leaky at the ends of the tubes; and unless stayed, independently of the tubes, the tube plates will be forced asunder by the pressure of the steam.

Galvanic Action. It is very necessary, however, in designing marine engines and boilers, to guard against the destructive effects of galvanic action in all cases where two metals of different degrees of solubility in salt water (such as iron and brass) are placed in juxtaposition; when the iron, being the most oxidable metal, suffers a rapid corrosion. To prevent this action, as well as for economy, it is now usual to furnish marine boilers with iron tubes in place of brass, from $2\frac{1}{2}$ to $3\frac{1}{4}$ inches external diameter, and about $\frac{3}{32}$ to $\frac{1}{8}$ inch thick.

Clothing of boilers. Although it must be allowed that in all cases the clothing of marine boilers with non-conducting substances, such as hair-felt, wood, &c., is highly advantageous for the production of steam, yet this practice is alleged in some instances to have induced a rapid wear in the plates of the boiler. This unlooked-for result is most apparent in boilers which are frequently used and disused alternately, the corrosion taking place on the interior surface. The conjecture as to its cause is, that owing to the alternate wetting and drying of the plates of the *clothed* boiler, the rust may be more apt to scale off, and thus constantly present a clean surface for corrosion, this action recurring each time that the water is blown out of the boiler; but when, on the other hand, the boiler is *naked*, the internal surface never thoroughly dries, owing to the evaporation being checked by the low temperature, and the saturation of the confined air. The clothing of marine boilers which make long voyages is never attended with these injurious results, nor are they ever experienced in land boilers.

Bedding of boilers. The manner of *bedding* marine boilers is a point of much importance, and will materially affect the durability of the bottom plates. A good practice, in the English service as well as in our own, is to form a close platform of 2-inch fir deals over the keelsons, upon which the boiler is then bedded with a cement or mastic of lime and drying oil, laid about 1 inch thick over the timber. This sets quite hard, and prevents the bilge-water (which in wooden ships is highly acid) from washing up to and corroding the plates of the bottom. The cement is also intended to stop any leaks which may break out in the bottom of the boiler, as well as to strengthen it in the event of a rapid corrosion taking place inside. Unfortunately, a perfectly close contact cannot be maintained between the iron and the cement, from the unequal degree of expansion of the two materials by heat, so that the effect of a leak in the bottom plates is frequently that the brine extends itself for a large space between the two surfaces, and the wear of the boiler is increased instead of diminished. The best practice is, perhaps, that of resting the boiler on saddles of cast iron fixed on the boiler bearers, which leaves the bottom exposed for examination, painting, and small repairs if necessary, the bottom of the vessel under the boilers being at the same time kept clean and dry by the bilge-pumps.

Duration of iron boilers. As will be easily understood from the preceding remarks, the duration of an iron boiler varies according to the treatment it has received, and the facilities afforded by its construction for thoroughly examining, cleaning, and repairing the parts. Thus, while some have been worn out with three years' service, others of the same thickness of plate have lasted six and eight years. A government steamer is seldom in commission longer than three years at one time, and at the end of this period the boilers very frequently require renewal; or if they are not much worn, and if the vessel

be of such a class that she will probably not be sent on foreign service, the boilers are repaired and made to serve another two, or it may be, four years.

Miscellaneous remarks about boilers. All the rough nuts about a steam vessel which require to be screwed and unscrewed frequently, such as the bolts of the man-hole and mud-hole doors of the boiler, should have large square nuts, and the bolts should be strong and have coarse threads. Hexagonal nuts speedily become round in the hands of the firemen, by whom the mud-hole and man-hole doors are generally taken off, and fine threads soon get stripped and overrun. It is much the safest way to put on both mud-hole and man-hole doors from the inside, with cross-bars on the outside to keep them closed. The plan sometimes followed of putting on mud-hole doors from the outside, and securing them by one or two bolts, is a practice to be reprehended as full of danger, as, if the thread strips or the bolt breaks, the door will fly off, and the boiling water rush out, scalding every one in the vicinity. Mud-hole doors of this kind, even if they leak, cannot be screwed up to tighten them when the steam is up, as there is a perpetual risk, in tightening the doors, of stripping the thread or breaking the bolt.

The tops and steam-chests of boilers, and the bottoms of the ash-pits, are the first parts to give way. The steam-chest wears chiefly from internal action; in some cases the iron exfoliates in the form of a black oxide, which separates in flakes like the leaves of a book; while in other cases the iron is, as it were, gouged away, and the heads of the rivets are worn off as if by an acid. It is most important that a remedy should be found for this evil. The ash-pits are worn away chiefly by the wetting of the ashes in the stoke-hole, and it is expedient to apply shield-plates to those places when the boilers are made, which plates only will be exposed to wear, and may be easily renewed, leaving the ash-pits untouched. The best method of setting boilers appears to be to set them on a platform, and care must be taken that no projecting copper bolts touch the boilers in any part, as they will be very likely to corrode the points of contact into holes. The platform may consist of 3-inch planking, laid across the keelsons, nailed with iron nails, and caulked and puttied like a deck. The surface may then be painted over with thin putty, and fore and aft boards of about half the thickness may then be laid down, the heads of the nails being well punched down. This platform must next be covered with mastic cement, and the cement must be caulked beneath the boiler by means of wooden caulking tools, so as completely to fill every vacuity. Coomings of wood must next be laid round the boiler, to confine the cement; and the space between the cement and the boiler must be caulked full of cement and be smoothed off with a slope to shed the water.

The large rivets sometimes used as stays for the shells of boilers, are objectionable, as the heads very often come off, and if the fracture be between the boilers in a position not accessible from the outside, it will be necessary to empty the faulty boiler of its water, in order to repair the defect. The sides of furnaces should always be made to incline to each other, so that the crown is not so wide as the fire-bars, and it is a good arrangement to place the bars adjoining the sides close against the sides throughout their length, so as to leave no air-space in that situation. By this arrangement, the intensity of the heat acting immediately against the plates of the sides is diminished. A crack in a plate is most conveniently closed by boring several holes along its length, and closing them with rivets having large heads, which cover over the defects. If a patch be applied to the top of a furnace or flue, it is better to apply it from the inside of the boiler rather than from the flue, as in the latter case a recess is left into which deposit falls, and a hole is likely then to be burnt again in the same place. If the furnace mouth be contracted by bending in the sides of the furnace, as is the general practice, it is necessary to be very careful that scale does not accumulate in these corners, else they will be very liable to be burnt into holes.

Respecting fire-bridges, the preferable practice, on the whole, appears to be to construct them of brick, rather than to make them water bridges, as with water bridges there is often trouble from the cracking of the plates. If water bridges, however, be used, they should be made with a great inclination in the breadth of the furnace, to facilitate the escape of the steam. Flame-bridges have been introduced into the furnace flues of steam vessels on some occasions, consisting of a pile of fire-brick, between which and the sides of the flue only a space of about three inches is left for the flame and smoke to pass through, and the flame is spread in a sheet over the interior of the flue. Where the flue is very large, the use of a flame-bridge appears to be expedient, and in land boilers with large internal tubes, its use has been attended with beneficial results; but in the majority of marine boilers, we believe that it will prove of but little service.

Explosion. Most explosions are found to arise either from undue pressure of the steam, or from the overheating of the plates composing the boiler. The plates of the boiler may become overheated either in consequence of a want of water in the boiler, or from such a configuration of the internal parts of the boiler that the steam when formed cannot escape freely to the surface. The bottoms of large flues upon which the flame beats down are very liable to injury from this cause; and the iron in such a case will probably be softened by the heat, and in all probability will collapse upwards.

The plugs of fusible metal sometimes introduced into boilers to obviate explosions by melting out before the steam can reach any high temperature, are found in practice to be of little avail. The compound metal is not homogeneous, and the more fusible of the metals is melted first, and is forced by the pressure of the steam out of the interstices of the less fusible metal, leaving its place to be supplied by the debris which all water supplies. The consequence is that the plug ceases to be fusible metal of the kind originally introduced, and cannot be melted by the steam even at a pressure and temperature much above that fixed as the requisite fusing point. In tubular boilers, however, it is a good plan to introduce lead plugs in the tops of the fireboxes—not with the idea that they will be melted by the steam where its pressure gets high, but to be melted out, and give notice of danger, should the water fall too low.

Every boiler should be furnished with a steam-gauge, which may give indication of danger should the pressure become too great, and the passages leading to the safety-valves should have no connection

with the pipes leading to the stop-valves. In some cases stop-valves have been lifted from their seats and forced into the mouth of the pipe, so that no steam could escape thereby; and in consequence of the safety-valve pipe springing from the pipe connecting the boilers, the boiler thus blocked up was in great danger of bursting, and would have burst if the fires had not been immediately drawn. In the case of any derangement of the safety-valve, or of the cone in the waste steam-pipe of a steam vessel getting loose, and blocking up the mouth of the pipe, the pressure in the boiler may be eased by opening the blow-through valves of the engines, and the steam-gauge will in all cases tell whether any undue pressure exists. See Gauge.

Extract from a report made by the Association in Manchester, for preventing steam boiler explosions, and for effecting economy in the raising and use of steam: "The chief inspector has reported several cases of imperfection tending to accidents, and, in particular, has found many flues so constructed as to transmit heat directly to the steam in the boiler, not only when the water is deficient, but when at its daily working level, thus surcharging the steam with heat, and endowing it with one essential element of explosive power, which may be instantly developed by the admixture of water, by agitation or otherwise. The fact that steam, in contact with water in a quiescent state, may be heated to 500° or upwards, without any corresponding effect on the steam gauge, or proportionate increase of pressure, appears to be established on good authority. But the precise condition under which the surplus heat thus accumulated in the steam may combine with water to produce explosion, is not fully known.

"Our attention has been directed—1. To an examination of all boilers placed under our inspection, with a view to ascertain, as correctly as possible, their actual condition, and whether they were adapted to their ordinary working pressure; also, whether they were provided with the requisite mountings, and if the same were kept in good working order.—2. In those cases of explosions which have taken place in the neighborhood, to an investigation of the peculiar circumstances connected therewith, in order, if possible, to ascertain the real cause, and the best means of preventing the recurrence of such accidents.—3. To ascertain by comparison the most advantageous construction, dimensions, and working of boilers in regard to safety, economy of fuel, and durability.—4. To ascertain the most economical system of employing steam as a motive power.

"The number and description of boilers at present under our inspection are as follows, viz.:—

Description.	Pressure per square inch. 15 ℔ or under.	16 ℔ to 30.	31 ℔ to 45.	46 ℔ to 60.	61 ℔ to 75.	76 ℔ to 80.	Number.
Cylindrical, with internal flues	83	274	144	60	28	—	589
Cylindrical, without do.	10	12	10	6	7	—	45
Galloway's patent boilers	2	35	48	12	—	—	97
Multitubular "	12	9	31	32	2	1	87
Butterley "	43	20	1	—	—	—	64
Wagon "	38	—	—	—	—	—	38
Total	188	350	234	110	37	1	920

Of the above, 81, or nearly nine per cent., have been found to be in a dangerous state, from the following causes, viz.:—

Construction or strength not adapted to the working pressure	24
Defects in the plates or angle iron	9
Defects in the boiler mountings	26
Injury sustained from deficiency of water	19
Ditto " deposit of scale	3
Total	81

In addition to the above 19, rendered dangerous from deficiency of water, there are 14 others which have been injured to a less extent from the same cause. This is evidently the most frequent cause of explosion, as will be explained hereafter; and as it is important to provide such means of prevention as will be effective in cases of negligence on the part of the fireman, we would suggest, first, the general adoption of open stand-pipes, where applicable, or safety valves, in connection with a float, to allow the escape of steam, whenever the water falls below the fixed limit.—2. The use of fusible metal plugs, fixed on the top of the flues above the fire. These should stand sufficiently high to melt before any part of the flues could be uncovered with water. The usual practice of inserting a lead rivet or plug in one of the plates is worse than useless, inasmuch as owing to the inclination usually given in setting boilers, a considerable portion of the flue must be exposed, and may even become red-hot, before such lead plug can be melted; under which circumstances an explosion is the probable consequence.

"Although the possibility of surcharging steam, while in contact with water, is still disputed by many engineers in this country, this question was satisfactorily solved by a committee of the Franklin Institute, in America, above twenty years ago. In the report of this committee, it is stated that 'the temperature was carried to 533 degrees Faht., when the pressure, shown by the gauge, was 6·82 atmospheres: while saturated steam, at that temperature, would have had a pressure of more than 60 atmospheres;' and further, 'these experiments, which lasted more than two hours, show that the surcharged steam remained in contact with water without acquiring from it the water necessary to convert it into saturated steam, but retaining its surcharged state.' Several instances which have come under our own observation might be adduced in confirmation of the experiments of these gentlemen, but we shall only mention one, which lately occurred, as sufficient for our present purpose. The boiler

referred to, contained two internal furnaces, uniting in one flue, and had been filled with water to the usual height by a pipe leading from a reservoir. The end of this pipe was about 9 inches below the top of the furnaces. About two hours after lighting the fires, the steam (being at 8 lb, as indicated by the gauge) was turned into the mill for the purpose of warming it. Shortly after this the attendant observed that the water had disappeared from the gauge glass, and was forced back into the reservoir, the valve on the feed-pipe not having been entirely closed. At this time the upper part of the furnaces, above the surface of the water, had become red-hot, and the temperature of the steam was such that a block of wood, resting on the top of the boiler, was converted into black charcoal, and yet the pressure never exceeded 8 lb. The communication with the reservoir having been closed, the fire doors opened, and the damper shut, the boiler was allowed gradually to cool; and although the tops of the furnaces were depressed, no explosion took place. From this it is evident that steam may be raised to a high temperature, while in contact with water, and yet remain at a low pressure. And this condition can only arise from a deficiency of water in such steam; we may reasonably infer, that if this could by any means be supplied, we should have an almost instantaneous increase of density and pressure proportionate to the degree of saturation. This will fully account for the difference in intensity of many explosions, and why these should so frequently occur immediately after starting the engine, admitting water into the boiler, or lifting the safety valve, all of which tend to produce agitation of the water, and to promote its diffusion amongst the steam. Although this theory of boiler explosions, which was advanced by the late Mr. Perkins many years ago, has not hitherto been generally admitted, certainly the facts which have come under our own observation seem fully to confirm its accuracy. The two last subjects which have been proposed for investigation require a greater amount of data than we have as yet been able to obtain; and although we have had occasion to remark great errors in many of the present modes of employing high-pressure steam, we should not now be justified in expressing a decided opinion as to which system is positively the best, nor which is the best construction of boiler. In connection with the working of boilers, the subject of smoke-prevention has not been overlooked. Our experience on this subject tends to the conclusion, that without much difficulty or expense the smoke nuisance may be greatly abated, in almost every description of boiler, and that this will be accompanied by a saving of fuel, provided such attention as might reasonably be expected be given by the fireman."

**Explosions from Incrustations.*—A boiler bottom getting *red* hot is not likely to take place gradually while the engine is at work, the water-feeding apparatus in order, and the boiler kept clean. But if a boiler is allowed to become dirty, or covered with indurated or incrusted earthy matter, interposed between the iron and the water, there is then no difficulty in accounting for such circumstances producing an explosion at any time; and the way in which it operates towards that end appears to be something like the following:

It is known that an internal coating of incrustation, or boiler scale, is liable to crack and separate into large pieces, which are thrown off from the boiler bottom at some particular degree of temperature, depending upon the thickness of the scale and the kind of substance of which it is formed. We can easily suppose that by a little hard firing, and unduly heating the boiler, a large portion of scale may be suddenly detached, uncovering a considerable area at a temperature something exceeding the *maximum evaporating point*, which is well known to be considerably under the lowest red heat of iron. Now, the first effect produced will evidently be a certain amount of repulsion between the overheated iron and the water, which may continue for several seconds, and perhaps for a few minutes; this may account for the sudden *decrease* in the supply of steam that has sometimes been observed just before the explosion of a boiler has taken place. There must also be a gradual diminution of temperature during this short space of time, in that part of the overheated iron which is exposed to the water—creating a contraction of the metal—increasing as the decreasing temperature of the iron approaches the maximum evaporating point, which is at about 350° to 400° Fahrenheit, and causing a corresponding strain on the rivets in the boiler bottom. The direction of this strain may generally be traced on examining the bottom plates of any old boiler, and will be found to radiate in lines proceeding from the part which has been most acted on by the fire.

The next and concluding step, in case of the metal not being able to withstand the strain caused by its own contraction, will either be a sudden crack or fracture in some direction across this exposed part, or, what most generally happens when an explosion results, the sudden giving way of some bad seam of rivets, which the most nearly coincides or is parallel with the direction of what would otherwise be the true line of fracture. This may possibly be at some distance from the part which has been overheated, thereby giving the increased effect of great leverage to the pressure acting upon all that portion of the boiler included between the overheated part and the actual line of fracture. Now the consequence is, not perhaps that this portion is blown out, as would most probably be the case with very *bad* iron, but it will be bent or doubled back, the line of flexure running across the hottest or the weakest part of the iron. This may help to account for the remarkable way in which we sometimes find exploded boilers twisted and doubled up. A rupture being thus effected, an explosion is inevitable, if the hole be sufficiently large.

When an incrusted boiler bottom becomes highly heated, and the water at the same time too low, it very commonly happens that a large quantity of water is immediately let in, when the consequences are similar to those just described: for the internal coating of scale being suddenly contracted by the cooling effect of the water admitted, it is detached in the same manner as it would have been by the expansion of the iron, and the same effects produced, although perhaps more speedily, as the water admitted will reduce the temperature of the exposed part of the boiler bottom more rapidly to the maximum evaporating point.

Whenever a boiler bottom is seen, or supposed to be, approaching to redness—and that can only

* Armstrong on steam boilers, 1856.

happen when the water is *not* boiling, or when the engine is standing—the engine-man should be cautioned against allowing a fresh supply of water to go into the boiler, whether the boiler is short of water or not, until after the engine has been some time at work. My advice to engine-men in such cases is *not to start the engine at all*, but to open the fire-doors and stand at a safe distance until all goes cool. I would not have him stop to pull the fires out, and on no account to open the safety valve, as being little less hazardous than starting the engine. If, indeed, he knows the safety valve to be overloaded or made fast, and the steam still continues to rise with the fire-doors open, the fires may then be quenched by a jet of water from a hose pipe, or other safe means.

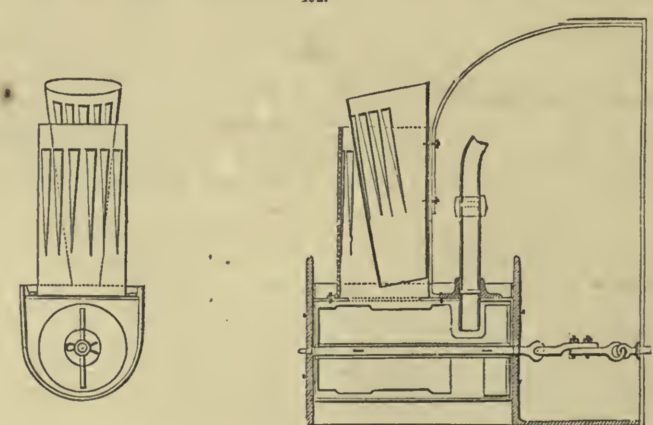
Deposit of Sediment.—All natural waters hold various solid matters in solution or suspension; when in the latter state they admit of being removed by filtration; but no system of filtration, on a scale sufficiently large to supply a moderate-sized steam engine at a light expense, has yet come into practical use. However, it occurred to a gentleman several years ago to hit upon a very simple and effectual substitute. And that was, instead of separating the water from the dirt, before passing it into the boiler, he separates and *collects* the dirt from the water, after it is in the boiler, by means of a series of vessels, shelves, or trays, placed up and down the boiler, constituting, in fact, so many portions of what collectively might be considered a substitute for a false bottom, upon or into which all the matters held in suspension are deposited. This, in fact, is the whole of the principle of Mr. Anthony Scott's patent of 1827, which has been so frequently re-patented and re-registered since that time, like many bad copies of good pictures, some of them so very bad that the patentee, if he were living, would not know that they were even meant for imitations.

These sediment vessels operate much after the same manner as certain quiet still places do along the banks of rivers, in causing sand or mud to accumulate in them; making so many places of shelter, where any movable matters being accidentally deposited, they remain free from agitation and not disposed to move out. In a boiler containing *boiling* water, of course the same principle prevails; the steam rising from the boiler bottom—the sole cause of ebullition in all cases—being the agitating agent. In fact the water never boils within the internal vessel or sediment receiver, however violently it may boil externally; and the more violently the water boils the more rapidly the internal vessel collects all loose sediment floating about in the water. Excepting for calcareous incrustations, the process was perfectly successful in keeping a boiler clean. The only difficulty in its practical application was liability to neglect in cleaning out the collectors themselves when they got filled with deposit, and the necessity of emptying the boiler for that purpose.

For the above reasons it appeared desirable to the patentee to have his cleansing apparatus made *self-acting*, that is, to *clean itself out*, without interruption to the working of the engine, or letting down the steam; which improvement R. Armstrong effected in 1829, when the first complete boiler-cleansing *machine* was executed and applied to a boiler at the calico-printing works of Messrs. Thomas Marsland and Son, in Stockport, who afterwards had fifteen boilers so fitted. Since the above period they have continued in general use in Lancashire.

The general form of this apparatus is shown by fig. 492. Many hundreds have been made and adapted to various kinds of boilers, including those of railway locomotives and steamboats. In the

492.



SCALE.—⅛th inch = 1 foot.
Longitudinal Section and Elevation of Collectors.

last-mentioned cases, and in all cases where there is no fire *under* the boiler bottom, they are, generally speaking, unnecessary, except for the purpose of preventing priming, which they most effectually do when that arises from dirty water. For this purpose the upper conical-shaped vessel is made with the narrow collecting apertures adjusted partly above and partly below the surface of the water. In this way it is used by opening the valve at the end of the boiler, and putting the handle of the agitator in motion for half a minute, by which the contents of the receiver at the bottom of the boiler are dis-

charged upwards through the pipe on the right hand. This operation creates a current, which draws all the *scum* and *froth* that *cause* the *priming*, from all parts of the water surface into the collecting vessel and down into the receiver, whence they are discharged to the outside of the boiler by a repetition of the process.

By thus *skimming* the dirt from the top of the water, clean *dry* steam is supplied to the cylinder of an engine instead of a mixture of steam and dirty water, causing, in ordinary cases, such great waste of power by friction on the piston and piston-rod, and unnecessary consumption of tallow.

Great consumption of lubricating material is always proof of imperfection in machinery. Instances are not wanting of large stationary engines working for months together without grease of any kind to the piston-rod, contrasting greatly with the lavish use of that material in marine engines, rendered necessary mainly by the greater liability to prime. The old device of throwing tallow into a steam-boat boiler, in order to *prevent* priming, is still without a satisfactory theory. The only suggestion to account for it worth attention, is one by Mr. W. Keld Whytehead, C. E., in an article on the priming of boilers, in the "Artizan Journal" for December, 1848, in which he supposes that, as the tallow requires a very high temperature to vaporise it, it "consequently floats *like a hot plate on the surface of the water*, and tends to separate the particles of water from the steam as they rise."

Calcareous Incrustations.—When the incrustation forming on the inside of boilers consists principally of argillaceous or silicious matters, it is easily prevented by the use of one or the other of the above described apparatus. When, however, any considerable proportion is either *carbonate* or *sulphate of lime*, considerable difficulty is experienced in preventing its formation to an injurious extent. The latter substance more especially, it is well known, has withstood all attempts at complete prevention by chemical means, except such as would be also injurious to the iron. The principal remedial agent that has been found beneficial in any degree to mitigate the effects of this substance, is *crushed potato*, which does not act chemically, but mechanically, the pulp of the potato being supposed to envelope the crystals of the sulphate of lime as they form, and prevent their adhesion to each other.

With respect to the incrustations of carbonate of lime, the case is very different. It admits of various methods of preventing its formation by chemical reagents. The most popular of the patent remedies is that of Dr. Ritterbandt. This plan is to put into the boiler daily a small quantity of muriate of ammonia, or sal-ammoniac, the effect of which is, that any bi-carbonate of lime in solution in the water is decomposed, the muriatic acid of the muriate of ammonia taking the lime and *keeping it in solution*, while the carbonic acid joins the ammonia, forming carbonate of ammonia, which passes off along with the steam. It need not be observed that this remedy can have no effect whatever in preventing the sulphate of lime incrustation.

The theory of the following remedy is something like the reverse of the foregoing. It is to put into the boiler daily or weekly a quantity of quick or newly-slacked lime, the effect of which is to convert the *soluble bi-carbonate* into the *insoluble carbonate* of lime, which, instead of being kept in solution as muriate of lime is in Dr. Ritterbandt's remedy, is precipitated and collected without any trouble by sediment collectors, or collected and discharged from the boiler by the cleansing machine. This putting in of lime to take out lime is a nice application of Dr. Clark's simple and efficacious method for purifying water on a large scale, now so well known and generally approved by water-works companies.

In Lancashire, where generally a great portion of the boiler scale is sulphate of lime, it has long been a practice to use ox-feet, or any animal substance convertible into jelly by boiling, with good effect. But they are liable to promote priming, and, like potatoes, they require frequent renewal. One English patent, now expired, specified the use of all kinds of vegetable matter or extract without exception, preferring that which gives out the greatest quantity of *coloring matter*, as logwood, bark, or tan. Also turf, peat, manure, leaves, saw-dust, and charcoal. Other patentees recommend urine, glue, blood, dung, and night-soil. Also sugar, starch, treacle, flour, malt, and the bottoms or settlings of beer barrels. Most of the above articles may be used with advantage where there is not much of the sulphate, but they all act mechanically. Tan and salt are the principal ingredients in some of the best of the foreign patents, which generally also contain some corrosive materials that are difficult to particularise and hazardous to use.

Incrustation.—The incrustation of boilers by saline deposits was a much more important subject at one time than it is now, as nothing has been more clearly established, of late years, than that boilers may be preserved effectually from any injurious incrustation by abundant blowing off. Brine-pumps are now in extensive use for withdrawing a certain quantity of water at every stroke of the engine; and the water so withdrawn has to pass through or among pipes carrying the feed-water to the boiler, so that some interchange of heat is there effected. These refrigerators, however, as they are grotesquely called, are in some respects bad things: the quantity of heat they save is, we believe, inappreciable; and the small pipes of which they are built up are liable to get choked, thereby endangering the boiler by the unconscious concentration of its contents. To guard against this danger, every engine fitted with brine-pumps should be provided with an hydrometer for telling the specific gravity of the water in the boiler, so that the engineer may not be cheated by the defective action of the pumps, or suppose that they are operating when they are really inert. In the case of blowing out a boiler in the usual way, the engineer looks at his glass gauge-tube, and keeps the blow-off cock open until the water-level has descended through the required distance, so that, under these circumstances, no doubt can arise that the boiler has been emptied of a certain quantity of water; but there is no such assurance in the case of the continuous extraction of the water, either by brine-pumps or by a continuous blow-off; and all boilers using either of these expedients should be fitted with hydrometer gauges as a precaution against the contents of the boiler being suffered to reach an injurious concentration. The prevailing fault among engineers, however, is that they do not blow off enough, the idea probably being that a considerable check is given to the generation of the steam by the introduction of colder water in lieu of the water abstracted; but the waste of heat by effectual blowing off is very inconsiderable—much less, in-

deed, than is occasioned by the difficulty of getting steam from brine, or of transmitting heat to the water through flues covered with incrustation, much of which heat, in consequence, ascends the chimney. There is no gain, therefore, in any respect, by penuriousness in blowing off; and there is much injury to the boiler, for incrusted plates become overheated; they blister, crack, and get burned out, and make expensive repairs indispensable. Proprietors of engines should accept of *no excuse* for the accumulation of salt or incrustation within their boilers; for such deposits arise altogether from insufficient blowing off.

The best method of scaling boilers appears to be by lighting a train of shavings in the furnaces and flues after the boilers have been emptied of water. The rapid expansion of the metal, thus occasioned, causes the scale to crack off; and, if the flues be then washed down with a hose, the scale will fall to the bottom of the boiler, and will issue out with the water on taking off the mud-hole doors. This plan of scaling, however, is one that the engineer must execute himself, and must not intrust to firemen or other subordinates, as the metal of the boiler might be damaged if the heat were made too great. The safety-valve should, obviously, be kept open while the boiler is being heated and cooled, to obviate any pressure or exhaustion within it. This plan of scaling, however, will seldom be necessary if due attention be paid to blowing off by the engineer; and if the quantity of scale be inconsiderable, or partial in its attachment, the best plan will be to chip it off with a hatchet-faced hammer, and then wash down the flues with the hose, as before described.

Corrosion.—The corrosion of boilers is one of the most obscure subjects in the whole range of engineering. Marine boilers seldom last more than four or five years, whereas land boilers, made of the same quality of iron, often last eighteen or twenty years; yet the difference in durability is not the effect of any chemical action upon the iron by the contact of sea-water, for the flues of marine boilers rarely show any deterioration from this cause, and, even in worn-out marine boilers, the hammer-marks on the flues are as conspicuous as at the time of their formation. The thin film of scale spread over the internal parts of the boiler would, of itself, preserve that part of the iron from corrosion which is situated below the water-level; but, whatever be the cause, it is a rare thing to find any internal corrosion of a boiler using salt water in those parts of the boiler with which the water comes in contact. The cause, therefore, of the rapid wearing out of marine boilers is not traceable to the chemical action of salt water, and steamers provided with Hall's condensers, which supply the boilers with fresh water, have not reaped much benefit in the durability of their boilers. The operation of the steam in corroding the interior of the boiler is most capricious—the parts which are most rapidly worn away in one boiler being untouched in another, and in some cases one side of a steam-chest will be very much wasted away while the opposite side remains uninjured. Sometimes the iron exfoliates in the shape of a black oxide which comes away in flakes like the leaves of a book, while in other cases the iron appears as if eaten away by a strong acid which had a solvent action upon it. The application of felt to the outside of a boiler, has in several cases been found to accelerate sensibly its internal corrosion. Boilers in which there is a large accumulation of scale appear to be more corroded than where there is no such deposite, and where the funnel passes through the steam-chest the iron of the steam-chest is invariably much more corroded than where the funnel does not pass through it. These facts appear to indicate that the internal corrosion of marine boilers is attributable chiefly to the existence of surcharged steam within them, which is steam to which an additional quantity of heat has been communicated subsequently to its generation, so that its temperature is greater than is due to its elastic force; and on this hypothesis the observed facts relative to corrosion become easily explicable. Felt applied to the outside of a boiler may accelerate its internal corrosion by keeping the steam in a surcharged state, when by the dispersion of a part of the heat it would cease to be in that state. Boilers in which there is a large accumulation of scale must have worked with the water very salt, which necessarily produces surcharged steam; for the temperature of steam cannot be less than that of the water from which it is generated, and inasmuch as the boiling point of water, under any given pressure, rises with the saltness of the water, the temperature of the steam must rise with the saltness of the water, the pressure remaining the same; or in other words the steam must have a higher temperature than is due to its elastic force, or be in the state of surcharged steam. The circumstance of the chimney-flue passing through the steam will manifestly surcharge the steam with heat, so that all the circumstances which are found to accelerate corrosion are, it appears, such as would also induce the formation of surcharged steam. Besides, the natural effect of surcharged steam is to oxidate the iron with which it is in contact, as is illustrated by the familiar process for making hydrogen gas by sending steam through a red-hot tube filled with pieces of iron; and although the action of the surcharged steam in a boiler is necessarily very much weaker than where the iron is red-hot, it manifestly must have *some* oxidizing effect, and the amount of corrosion produced may be very material where the action is perpetual. Boilers with a large extent of heating-surface, or with descending flues circulating through the cooler water in the bottom of the boiler before ascending the chimney, will be less corroded internally than boilers in which a large quantity of the heat passes away in the smoke. If these views be correct, then to prevent the internal corrosion of marine boilers it is only necessary to take care that the water in the boiler shall be as fresh as possible, and that the root of the chimney shall either be lined with fire-brick, or not go through the steam at all.

Priming is the tendency of the water in the boiler to foam and pass in a state of spray into the cylinder along with the steam, and when in too great a quantity to escape through the steam port in the return stroke, it infallibly breaks down the engine. This effect must invariably follow the priming of a sufficient quantity of water in the cylinder of a beam engine in a factory, because it is not and cannot be expected to be calculated to withstand a sudden *blow*, and such it is in reality. For if the water primes into the cylinder in the down stroke, it must remain on the top of the piston until it strikes against the cylinder cover in the up stroke, with more or less violence according to the quantity. From the incompressibility of water, the effect is the same as if a piece of iron of equal thickness to the

depth of water on the piston was suddenly inserted in its place. The tremendous effect sometimes produced when a large engine breaks down from this cause, may easily be conceived; for as the vacant space left for clearance at the top of the cylinder is generally about the same depth in large as in small engines, the intruding body of water strikes the cylinder cover with a proportionally greater force. Generally the accident does not end with merely straining or breaking the crank-pin, which may be the extent of the injury in small engines; but the momentum of the beam is added to that of the fly-wheel, and their combined force is exerted directly in splitting the cylinder, or tearing off the cylinder cover, thence effectually demolishing all the rods and gearing. Priming arises from insufficient steam room, an inadequate area of water-level, or the use of dirty water in the boiler; the last of these instigations may be remedied by the use of collecting vessels, but the other defects are only to be corrected either by a suitable enlargement of the boiler, or by increasing the pressure and working more expansively. Closing the throttle-valves of an engine partially will generally diminish the amount of priming, and opening the safety-valve suddenly will generally set it astir. A steam vessel coming from salt into fresh water is much more liable to prime than if she had remained in salt water, or never ventured out of fresh. This is to be accounted for by the higher heat at which salt water boils, so that casting fresh water among it is in some measure like casting water among molten metal, and the priming is in this case the effect of the rapid production of steam. One of the best palliatives of priming appears to be the interposition of a perforated plate between the steam space and the water. The water appears to be broken up in dashing against a plate of this description, and the steam is liberated from its embrace. In cases in which an addition is made to a boiler or steam-chest, it will be the best way not to cut out a large hole in the boiler-shell for establishing a communication with the new chamber, but to bore a number of small holes for this purpose, so as to form a kind of sieve, through which a rush of water cannot ascend. In locomotives the same end is attained by the use of a perforated steam-pipe extending from end to end of the boiler. Such a contrivance draws the steam off equally from the surface instead of taking it from any one part; and boilers provided with it are enabled to work with so small a steam-space that the steam-domes are now being taken away from locomotives altogether. This expedient has not yet been adopted in steam vessels, though it appears to be applicable to them also with advantage. In some boilers priming appears to be mainly caused by a malformation which prevents the water from circulating freely, and the steam has therefore to pass up through the water, occasioning a great agitation, instead of the water being enabled to circulate with the ascending steam. The evil may be mitigated in such cases by the addition of pipes to the exterior of the boiler, which will permit a descending current to be established, to replace the water carried upward by the steam. This tendency of the water to rise into the cylinder is always considerably promoted by the very usual situation of the steam induction-pipe at the back end of the boiler, and seems to arise partly from the constant circulation of the water, which causes a current at the surface to set in the direction of the length of the boiler from the front end to the back. This circulation of water takes place in all oblong boilers, with a certain velocity depending on the ratio that the intensity of the heat in the furnace bears to the quantity of water to be kept heated, and is entirely independent of other causes, producing *waves*, which take their rise over the fire, and gradually increase in height as they pass towards the back part of the boiler.

That *waves* are always generated within a long boiler, when the engine is about to prime, is a singular but well-ascertained fact, as is shown by the frequent great and sudden depressions of the float at such times, especially if the latter happens to be placed at the contrary end of the boiler to that where the steam-pipe is fixed. In watching the rapidly-successive alternate elevations and depressions of the indicator, buoy, or float of a boiler in this condition, the priming may frequently be observed to recur periodically after intervals of a certain number of strokes, provided that the state of the fire and the load on the engine continue perfectly uniform. For the economical combustion of fuel, and arrangement of grates, see Fuel.

Smoke Prevention.—Hitherto, the practice has been to exclude as much air and heap on as much coal as possible, thus preventing a sufficient quantity of the common atmosphere getting into the furnace to secure complete combustion. The consequence was the gases were too slowly evolved, and passed away into the chimney in dense black columns, to poison the air of the surrounding neighborhood. This is prevented now, however, by a moderate enlargement of the fire-beds and flues, and the introduction of air to the surface of the fire through perforated doors, and plates placed between them and the fire. The furnace itself being constructed to admit the quantity of air required, for perfect combustion, the perforated plates secure such a mechanical division and distribution of the common atmosphere as to insure its becoming instantaneously heated, and promoting instead of retarding, as a column of cold air does, in a great degree the combustion sought. The whole mystery of all the smoke-preventing apparatuses now in public favor lies in this simple secret. The following is an analysis of experiments which have been made with Mr. Williams' Smoke Prevention apparatus. With the air wholly excluded, 251 lbs. of coal were consumed per hour, 1,239 lbs. of water were evaporated, the Pyrometrical heat being 381°; whereas, with the air admitted, the consumption of coal was only 236 lbs. per hour, the water evaporated 1662 lbs., and the temperature, as indicated by the Pyrometer, 901°; thus showing an immense saving of fuel and an extraordinary increase in the quantity of water evaporated, as indicated by the Pyrometric action.

BOILER PLATES, *Machine for punching.*—Fig. 493 is an elevation, Fig. 494 a plan, and Fig. 495 a side view of a punching-machine on a very improved principle, whereby the plates required for boilers and other purposes may be punched with the greatest possible accuracy, insuring at the same time very superior workmanship and great dispatch. It is usual in all ordinary punching-machines, first of all to mark out all the rivet-holes in the plate, by a template, with white paint, and then to place it as near as the eye will permit under the punch; by the contrivance of this machine, this operation is entirely dispensed with, it being only necessary to fix the plate to a travelling table, and then to adjust the various parts of the machine to the proper distance required between the rivets.

The large cast-iron frame *p* carries the several parts of the machinery, and also the two plummer-blocks for supporting the bearings of the lying shaft *a*, running the whole length of the building, for the purpose of working other machines; this frame is securely bolted to the wall which, added to its own weight, gives it great stability.

On the shafts *a*, connected together by the two coupling-boxes, is placed the crank *b*, the motion being communicated through the crank-pin to a connecting-rod *c*, to which is attached the upper lever *d*, being always at work, while the shaft *a* is revolving; the fulcrum of this lever is on the frame *p*. A lower lever *e* for raising and depressing the punching frame *f* has also its fulcrum on the same frame this last lever working only when the punching operation is being performed. On the top of th frame *p* is a lever and long rods *e'* for engaging and disengaging the machinery. The side view represented by Fig. 495, shows the machine at work, and by drawing down the lever *e'*, connected by the rods to the counterbalance weight, which will allow it to remain steady in any position, they are disengaged from the pin on the lever *d*, which at once ceases to communicate the motion to the lower or punching lever *e*; thus it will easily be understood that those parts of the machine constantly at work, are the lying shaft *a*, the crank *b*, the connecting-rod *c*, and the upper lever *d*.

The slide *f* for carrying the punches, works between V's, Fig. 494; one is fixed to the frame *p* by adjusting-screws, both on its face and sides, and by the curious shape given to the end of the lever *e*, this slide is made to rise and fall, the counterbalance weight and lever *g* being connected by two short links; on the bottom of the slide is screwed a small frame for carrying the punches, which may be taken out and replaced by others. The dies *i*, in which the punches work, are placed in a frame bolted to the frame *p*, and by unscrewing the small adjusting-screws, these may be taken out and replaced by others suitable to the different-sized punches that may be required. On the under side of the frame *p* is screwed a small stop, by which the circle punched from the plate is forced out as the slide rises.

In the front of the machine is placed a long table, supported by the carriages *o*, consisting of two columns and diagonal frame, having bolted to them two long bars, upon which the moveable table is made to slide; this table, as will be seen by Fig. 494, has a number of holes by which the plate to be punched is secured by clamps; it is advanced by the rope or chain *n* passing under the pulley, Figs. 493 and 494, and over a second one hung from the ceiling of the building, to which is connected a weight sufficiently heavy to draw forward the table and plate fixed to it; after travelling the length of the table *o*, it may be brought back by turning the winch-handle and spindle *l*, on which is a pinion for working the rack, fixed to the under side of the moveable table *m*.

By a very ingenious contrivance, forming part of this machine, the rivet-holes of boilers may be punched to very different pitches, a thing very much wanted in such cases as the repairing of old boilers, or replacing an old plate by a new one, where it is of the utmost importance to have the rivet-holes coinciding with the greatest accuracy, which may be better understood by supposing that in the length of a plate, one, two, or three additional rivet-holes may be required, which distance would have to be equally divided in the whole length of the plate. A description of this part of the machine will fully show how this operation is performed. On the end of the punching-lever *e* is screwed a small plate with a pin *j'*, adjustable by a screw working in the short mortise, Fig. 495; on the frame *p* is bolted a fulcrum piece for the lever and counterbalance weight *j*; to this lever a long rod is connected at its lower end, passing under the table *m*, and the lever *r* is fixed to it, as will be seen by the dotted lines in Fig. 494; it has also two stops or projecting pieces *r' r'* on its surface. A second lever *s* has its fulcrum fixed to the table *o*, one end of this lever being connected to the lever *r*, while the opposite end has on its surface two small pins *s' s'*; the fulcrum *s''* of this lever is adjustable by the two small screws shown in the plan, Fig. 494. A long notched bar *k* is fixed to the under side of the table *m* by screws, and the bar *t* has its fulcrum *t'* also fixed to it; this latter bar *t* is moveable on its centre, and may be placed at any angle by an adjusting-screw working in a mortise *t''*, where it may be fixed in any required position, as will be seen; it is by the angle given to this bar, that the regular increase of distance is obtained between the rivets. This is effected in the following manner:—As the lever *e* works on its centre, the pin *j'* to which it is fixed, strikes as it descends on the end of the lever *j*; its motion is then communicated to the long rod, passing under the table, for working the lever *r* backwards and forwards, it being fixed to the rod; as the latter lever moves, it alternately engages and disengages the stop or projecting pieces *r' r'* from the notched bar, allowing it at the same time to slide forward the distance between the rivets; while the bar *t* placed at the required angle, and working between the pins *s' s'* on the lever *s*, immediately effects the distance travelled by the lever *r*, which it shortens; by this arrangement the machine is made quite self-acting, but it may also be worked by the handle on the end of the rod *j*.

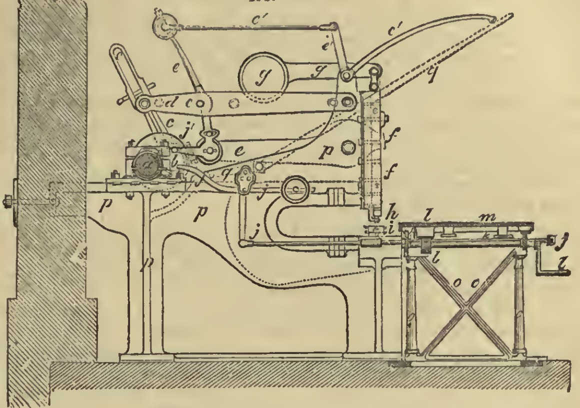
When it is required to change the punches *h* for different-sized holes, it is necessary, when replaced, to adjust them to the greatest possible accuracy in the dies *i*; this could not be done without stopping the whole line of shaft *a*, were it not for a provision made for that purpose; in such a case, the key in the upper part of the connecting-rod *c* is withdrawn; a block of wood is then placed between the frame and the lever *d*, whose fulcrum is on the side of the frame *p*, upon which it rests. It is of course understood that the punching-lever *d* is at rest, being disengaged from the pin *e'*; the result of this is the working of the long mortise of the connecting-rod up and down on the pin, without communicating any motion whatever; and by the lever *q*, worked gently by hand, and shown dotted in Figs. 494 and 495, the punching-lever *e* can be raised and lowered, communicating its alternate motion to the slide-frame, by which means the punches are with great facility adjusted in the dies *i*.

The jaws in the frame *p* are much strengthened by placing a square wrought-iron bar between them, in places provided for the purpose.

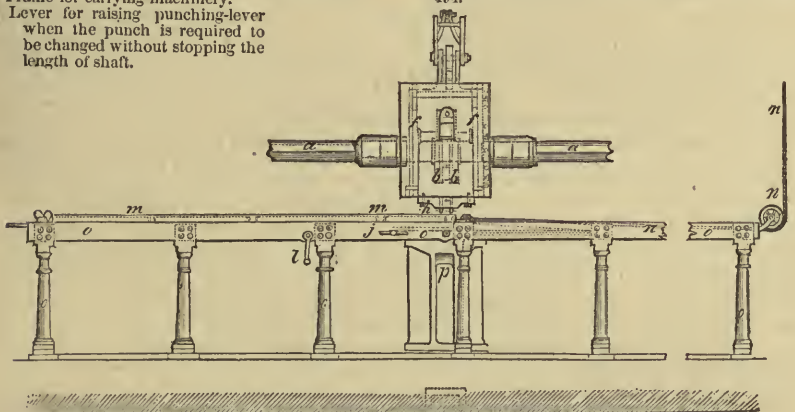
From the above description, it will be seen that the advantages possessed by this machine, more than compensate for the increased number of its parts, which are but few when compared with its superiority over those of ordinary construction.

a Shaft running through building.
b Crank.
c Connecting-rod.
d Upper lever worked by connecting-rod *c*.
e Lower or punching lever engaged or disengaged by means of rods, levers, and pin *e'*.
f Punching-frame raised or depressed by lever *e*, and counterbalance weight *g*.
g Lever and counterbalance weight.
h Punches.
i Die-frame.
j Self-acting rods, levers, and counterbalance weight, for engaging and disengaging notched bar from stops *r' r'*, worked by pin *j'*.
k Notched bar fixed to table and stopped by projecting stops *k* alternately on either side for each rivet.
Handle, pinion, and rack, for advancing table by hand.
m Moveable table for carrying plate to be punched, drawn along by rope or chain running over pulley *n*.
o Fixed tables supported by columns.
p Frame for carrying machinery.
q Lever for raising punching-lever when the punch is required to be changed without stopping the length of shaft.

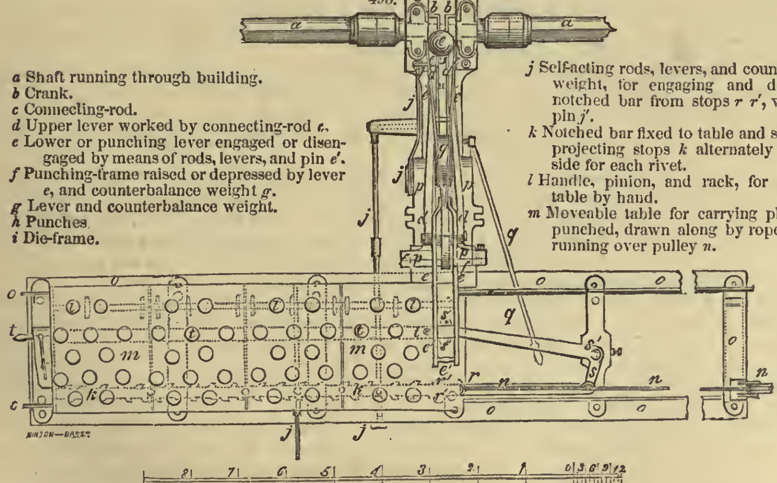
493.



494.



495.



a Shaft running through building.
b Crank.
c Connecting-rod.
d Upper lever worked by connecting-rod *c*.
e Lower or punching lever engaged or disengaged by means of rods, levers, and pin *e'*.
f Punching-frame raised or depressed by lever *e*, and counterbalance weight *g*.
g Lever and counterbalance weight.
h Punches.
i Die-frame.
j Self-acting rods, levers, and counterbalance weight, for engaging and disengaging notched bar from stops *r r'*, worked by pin *j'*.
k Notched bar fixed to table and stopped by projecting stops *k* alternately on either side for each rivet.
l Handle, pinion, and rack, for advancing table by hand.
m Moveable table for carrying plate to be punched, drawn along by rope or chain running over pulley *n*.
Rope and pulley for drawing along table *m*.
o Fixed table supported by columns.
p Frame for carrying machinery.
q Lever for raising punching-lever when the punch is required to be changed without stopping the length of shaft.
r Lever fixed at one end to rod *j*; on this lever is fixed two small projecting pieces *r' r'*.
s Lever with two guide-pins *s'*, having a moveable centre at *s''*.
t Bar for regulating the pitch of rivet-holes, working between pins *s' s'*; it has a fixed centre at *t'*, and may be placed at any angle by sliding in groove *t''*.

BOLTING-MILL, *for flour.*—A bolting-mill is the general name of a place where meal is sifted. But here the subject in question is particularly a dressing or bolting *machine* in common mills, by which either the bran is separated from the flour or meal, or the ground grain, ore, &c., is refined. The bolting machines most in use are—1st. The *common bolter ;* 2d. The *rotative* cylindric or prismatic *bolter ;* and 3d. the *brush-bolter.* Though they differ from each other in structure, the substantial arrangement consists in a kind of sieve of wire or horsehair, or of cotton or silk texture, of bolting cloth or of silk-gauze, either of which stuff is used according to the fineness of the meal required; the meshes or perforations of the one being smaller than those of another.

The peculiarity of the common bolter is, that the sifting is produced by its *shaking* motion; that of the cylindrical or prismatic bolter is, that the sifting is effected by its *rotative* motion, either alone, or by co-operation of the centrifugal power, or of beaters or similar apparatus.

The peculiarity of the brush-bolter is, that the sifting is effected by *brushes* placed in the interior of the bolter itself, which latter discharges its coarser contents into the bran-chest; while the meal or flour is taken up to the bolting-hutch.

The arrangement of the improved bolter in general use, will be perceived by Figs. 463, 464, 465, and 466, where Fig. 463 represents the bolting-machine in longitudinal section; Fig. 464 ground-plan, (but without the lid of the bolting-hutch :) Fig. 465 front, and Fig. 466 side-view of the hind part, together with the mechanism for effecting the shaking motion.

The oblong and closed bolting-hutch, marked by *a a*, is fastened to the meal-bench *b ;* and in its interior, at an angle of 15, or, at the most, 30 degrees, is placed the bolter or sifter *c c*, whose upper end is fastened to the scuttle *d*, Figs. 463 and 464, and whose lower end discharges its contents at the fore side of the hutch *a a.*

The bolter consists commonly of bolting-cloth or silk-gauze, of which two strips from 6 to 7 feet in length, and from 14 to 16 inches in breadth each, are sewed together lengthwise. The seams are edged, two inches broad; and the two ends of the bolter are likewise bordered with leather, for the purpose of fixing iron rings. The ring at the upper end is quadrangular, yet with rounded corners; it is 8 inches broad, and from 5 to 6 inches diameter. At about 2 feet down from the upper end of the bolter, two handles, (called bolter-ears, and marked by the letter *e*,) of strong sole-leather, are sewed to the sides, to serve for the reception of two arms *f f*, of the apparatus for effecting the shaking motion. The lower end of the tight-stretched bolter is placed in the aperture cut out in the slide *g* on the outside of the bolting-hutch; the shaking-arms *f f*, which are either covered with tin-plate, or with ends of cast-iron, are to be put through the two bolter-ears *e*; and the upper end of the sifter is to be placed on the outside of the scuttle *d*, in the notch of the wooden ledge *h*, Fig. 463, and fixed by the iron cramp *i*. At the lower end the screws *k k* of the slide *g* are designed to stretch the bolter as required.

The motion of the bolter may either be horizontal or perpendicular. The former is most general, as the bolter is more worn by the perpendicular motion. But it may be asserted that the case is almost entirely the reverse. For by the lateral motion the sides of the bolter are very much tossed, and so their threads too much stretched, especially when the shaking-arms *f f* stand out straight from the shaking-axis, forming thus an acute angle with the bolter. By the perpendicular motion the bolter is also violently tossed; however, this inconvenience may be removed by using curved arms, (like that marked by *f* in Fig. 463,) instead of rectilinear ones, and made either of timber or iron.

The vertical shaking motion of the bolter is produced in the following simple way: At the axis *l*, placed horizontally beneath the sifter, are fixed the two shaking-arms *f f ;* also at its projection the bent arm *m*, called the *bolter*, in which the *bolter-tongue* is, by means of a peg, fastened in a manner which allows of its turning. The bolter-tongue is pressed against the horizontal arm *o* of a vertical axis *p*, by the wooden or steel spring *q*, so firmly and continually that a retrograde motion results from the rebounding of this spring, while the advancing motion is effected by a second arm *r* of the axis *p*, which beats against three tenons *t*, and is pushed off again by them.

The power of this shaking motion can be modified according to the required fineness of the flour, or to the more or less fine bolting-cloth; and this is effected by displacing the bolter-tongue *n* in the wheel-scissors *m*, for which purpose both are perforated. However, the bolter is not suffered to move more than 3 inches up and down, as this is sufficient even for the coarsest grit, while a more vigorous movement would wear the bolter too much.

The upper millstone in a common mill, of 3 feet in diameter, making from 140 to 180 rotations a minute, each bolter, brought in connection with a set of such stones, will be moved up and down thrice so often, or 420 to 540 times in a minute. In order to be enabled to look frequently at the bolter, there is made in one of the side partitions of the bolting-hutch a large square aperture *u u*, commonly covered with a linen cloth *v*, Fig. 464. Another aperture *w*, about 6 inches high and wide, at the bottom of the hutch, is provided with a slide of wood or tin-plate, and serves as an outlet for the flour.

Beneath the lower end, or mouth of the bolter, is a small gutter *x*, made of wood or tin-plate, in order to facilitate the emptying of the grit or bran into the bran-chest below. The mouth of the bolter is covered with a cloth *y*, Fig. 465, pressed towards the mouth of the bow *z*, to prevent the flour-dust, joined to the grit and bran, from dusting away. The aperture in the side-partition, fig. 463, *u u*, is beside the curtain, fig. 464, *v*, closed with a door or slide, while on the other hand, the bran-chest is 1½ feet in length, and closed tightly.

The bolting-cloth used in bolting-mills consists generally of woollen, more seldom of silk texture, and is glued or gummed in a particular manner. According to the species of corn to be bolted, and to the fineness of the flour, the cloth is coarse or fine, both in the threads and the size of its perforations or meshes. There are more than a dozen sorts of cloth, which are selected according to the quantity of meshes in an inch square. The cloth is commonly from 14 to 16 inches broad, thus being adapted for the use of bolters from 10 to 12 inches in diameter. The English manufacture bolting-cloth noted for its good quality and durability; there are also in Germany superior manufacturers of this article especially at Linz, Berlin, and Breslau. The best quality bolting-cloth and silk-gauze is fabricated by

Dufour & Co., at Thal, in the Swiss canton of St. Gall, by *Hennecart*, at St. Quentin, in France, and by *Harlem Star*, in Holland.

We shall now describe those bolting-mills where the *cylindrical bolter* is used.

Formerly, in England and the United States, a bolting-mill of this description was used, in which the cylindrical bolter, put in circular motion with great celerity, consists of a kind of *reel*, framed in the following manner:—From a somewhat inclined axis, like radii, six arms or spokes project, which are connected with each other by six laths running parallel with the axis. This cylindrical frame is commonly, at the upper end, 22½ inches diameter, but at the lower end only 20½ inches, (in this case it is called *taper-reel;*) sometimes it is at both ends 22½ inches diameter, in which case it is called an *equal-reel*. The wider cylindrical bolter encloses the frame, and is at both ends (which are lined with leather) fastened to it. In the bolting-hutch are placed six wooden *beaters*, whose points stand off half an inch from those of the spokes. Now, as soon as the bolting-cloth is swelled by the rotation and centrifugal power, it strikes violently upon these beaters, and thus the finer elements of the flour are forced through the sides of the bolter, while the grit and bran proceed along the whole bolter into the bran-chest at the outside of the bolting-hutch.

Yet this bolting apparatus was not much adapted to the purpose, because the ends of the bolter could not be fixed firmly enough to prevent its unsteady, swinging motion, and its too violent striking upon the beaters, by which the bolting-cloth soon became defective. However, at present this bolting-mill is substantially improved by *James Ayton*.

Fig. 467 gives a side view of this improved machine, without the bolter, and without the front of the hutch. In the frame of the bolting-hutch *a a*, the apparatus is placed obliquely. By the axis *b b*, (made of forged iron,) and the disk *c*, the bolting-machine is brought in rotation. At the axis *b b* are fixed the two naves *d* and *e*, in a proper manner, and into both are placed four spokes *f f*, at right angles with each other. From each spoke to the corresponding opposite one, or from *f* to *f*, is distended a strip of bolting-cloth or duck *g*, 5 to 6 inches broad, fixed at the extremities of the spokes. The strips in the interior of the bolter form a kind of fanning-machine of about 20 inches diameter. Above the nave *d* is another one *h*, from which project six iron spokes, bent upwards, and connected with each other at their points by the wooden ring *k*, whose diameter is equal to that of the fanning-machine. Below the board partition *l l*, that separates the flour-hutch *m* from the bran-chest *n*, is a third nave *o*, from which project six steel springs *p*, whose points are bent into hooks, carefully rounded off and polished, that the handles of the bolter (which are fixed to them) may be spared as much as possible. This nave, which by Fig. 468 is twice represented on a larger scale, consists of three hoops *o q r*, of which the inner *q* is fastened to the square axis *b b;* the middle *o* revolves round the hoop *q*, and the outer *r* is fastened to the hoop *q* by four screws.

The bolter surrounding the fan-shaped reel is, by means of its handles at the lower end, fixed at the hooks of the six steel springs *p;* while its upper end, above the wooden ring *k*, is simply drawn together by a cord or string. As soon as the reel is in rapid rotation, the pressure of the air, produced by the fans and the centrifugal power, will swell the bolter, which at the same time is kept at a uniform concentric tension by the elasticity of the steel springs *p*.

Another substantial improvement of Ayton's bolting-mill is, that the six beaters *s*, lying round the bolter may, according to circumstances, be placed more or less near to it, even during the rotation. The manner of this arrangement may be perceived by Fig. 469, where the machinery, Fig. 467, is represented in a view from behind or before. On the outside of each of the partitions *l l* and *t t*, Fig. 467, is a broad iron ring *u*, Fig. 469, revolving round the axis *b*, in the small furrows of the six cramps marked with *v*. In both of these rings (on the front and back) are cut six eccentric slits *w w*, behind which, in the board partitions, there are cut out as many other slits, like radii of the axis *b b*, so that both kinds of slits are crossing each other. The beaters *s s*, Fig. 467, are (by means of screws *x*) brought into connection with the slits in such a manner, that they are moved to and fro in the slits of the partitions *l l* and *t t*, and thus approach and turn off from the bolter, as soon as the outside rings *u* (which are not connected with the axis *b b* itself) are turned round by the dented wheels *y*, Fig. 469. The whole perimeter of the rings is dented; only a part of it is shown in Fig. 469. The dented wheels are connected with another axis different from that marked with *b b*.

Through the hopper *z*, Fig. 467, is constantly running the ground grain as required for bolting; so that from the other end of the bolting-hutch only grit or bran, without mixture of flour, runs out.

This improved bolting-mill has this substantial advantage over the older one—that the movement of the air within the bolter is produced by the fans instead of the reel, and drives the flour towards the periphery in a more complete manner. Thus the flour gets easily through the perforations of the bolting-cloth, whose obstruction is almost entirely prevented by the trembling motion of the steel springs *p*. The beaters are also arranged so that they cannot much wear out the bolter.

While by the older machinery (with 170 to 200 rotations a minute) only two and a half to three sacks (measuring three bushels each) of grit are said to have been bolted in an hour, Ayton's improved mill bolts four sacks in the same time.

Notwithstanding this favorable result, the improved bolting-mill is not much used, for the reason that the bolter (as the weakest and most expensive part) is yet damaged by the beaters. The cylindrical bolter has recently been supplanted by a hexagonal or octagonal one, with great success.

Figs. 470 and 471 show the frame of this bolting-machine (which is in very general use in this country) in longitudinal section and front view. The front partition is omitted, to get a better view of the interior.

These bolters are made exclusively of silk bolting-cloth, manufactured by *Harlem Star*, in Holland. For two sets of five-feet millstones there are generally made bolters of 28 inches in diameter and of 90 feet in length, and of three different sorts of cloth; that is, 60 feet of the finest sort, No. 10 or 11; 24 feet of the middling sort, No. 5 or 9; and the remaining 6 feet (60+24+6=90) of the third or coarsest sort. No. 2, which latter is intended for separating the finer bran from the coarser.

The cloth is tentered round wooden frames similar to the above-described reels, of hexagonal or octagonal form, 20 inches in diameter, and from 18 to 20 feet in length. The cloth is fastened with pins to the wooden rings at both ends of the frame, and to six or eight laths running parallel with the axis, and resting on spokes.

Such bolters, as *a a*, Figs. 470 and 471, are commonly placed four in one hutch *b b*, that is, two above and two below, as in Figs. 470 and 471. They are placed somewhat obliquely, and, by means of the motive power *c c*, revolved all together by the wheel *d* of the axis, which also turns the wheel *e*. Each bolter makes generally 25 rotations in a minute. The flour-conveyers, *f* and *g*, are commonly put in motion by straps, (like the strap *h*, in Fig. 470,) they being highly adapted to the purpose, and moreover simple and cheap. The conveyers are intended to remove immediately the bolted flour from the hutch of each pair of bolters without opening the hutch.

The ground grain passes through the common plate-iron gutters *i i* into the two superior bolters, (where the cloth is of finer quality,) in such quantity as may be easily bolted by them. The mechanism applied for this purpose will be described below. The flour bolted in the upper half of these two bolters is somewhat finer than that bolted in their lower half, the former therefore being called extra-superfine, and the latter superfine. All this flour falls through the oblique partitions *k k*, Fig. 471, into the trough *l* of the upper conveyer. The wheels *m n*, Fig. 470, moving this conveyer, are covered by the roof *o*. The coarser parts, or the grit and bran, issuing from the mouth of the bolter, fall into the partition *p* of the bolting-hutch, and then, by means of the oblique board partition *q*, into the two lower bolters of coarser cloth a_1. Thence the bolted flour goes into the trough *r* of the lower conveyers *g*, and the bran goes from the bolter's mouth through the gutter *s*, Fig. 470.

The above-mentioned *extra-superfine* flour is, by means of the conveyer *f*, pushed to the wooden channel *t*, through which it then goes off into the flour-box, while the *superfine* flour is, by the channel *u*, conveyed into the upper partition of the hutch, enclosing the two lower bolters a_1 a_1. Hence, mixed with the flour of these bolters, it is by the lower conveyer *g* pushed to the channel *v*, through which it goes off into the *meal-elevator*, that brings it back to the *hopper-boy*. Thence, having been mingled with grit, it is conveyed once more into the bolter. In the case when the middling flour (or seconds) is ground for the second time, the flour bolted by the upper and lower bolters is intermixed and not reconveyed into the hopper-boy; but the gutter or channel *v* is shut, and the strap *h* (moving the conveyer *g*) crossed, which has the effect of conveying the flour to the gutter or channel *w*, (which then is to be shut up,) from whence it goes, together with the flour coming from the upper bolters down the gutter *x*, into the flour-box.

The mechanism by which the ground grain or meal is conveyed into each of the two superior bolters, is to be seen in Fig. 472, longitudinal section, and Fig. 473, front view, on a larger scale. The letter *y* marks a funnel, into which the ground mass falls down from a hopper-boy in a higher story, and thence upon the moveable spout *α*, resting on the axis *z*. The channel *i*, Fig. 471, is connected with this spout. At the fore part of the spout's side-boards are the cross-rails *β β*, by which, and by wedges, the shaking-bolt *γ* is fastened. At the upper mouth of the bolters is a cast-iron cross *δ*, Figs. 470 and 471, fastened to the axis, whose points are provided with heads, the forms of which may be seen by Figs. 471 and 472. During the rotation of the bolters, these heads touch upon the end point of the shaking-bolt *γ*, Fig. 472, which lifts the spout *α* up and down. Thus the spout is constantly in a shaking motion, and the mass heaped in the funnel *y* is conveyed by the gutter *i* into the bolter *a*. By means of the shutter *ε* the aperture at the bottom of the front partition of the funnel *y* can be widened or narrowed, according to circumstances.

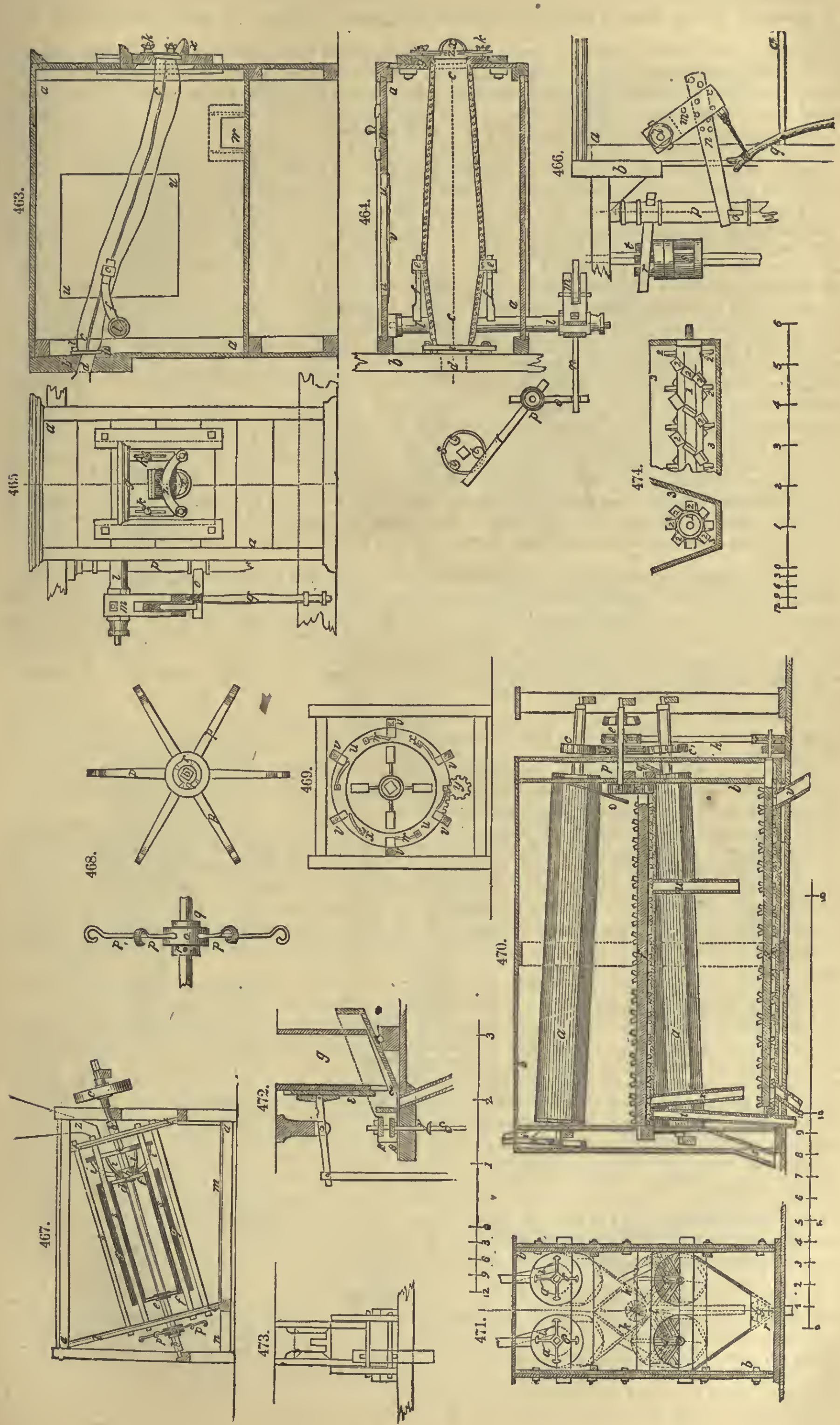
The *conveyers f* and *g* consist of a screw, as may be perceived by Fig. 474, where they are represented on a larger scale. The chief part is commonly an octagonal strong wooden axis 1, round which, in a helix, are put small wooden square tables 2, 2, at right angles to the axis.

These tables are generally 2¾ inches high and broad, and at the foot end half an inch thick, while the back lessens to a sharp edge. The front sides (which retain their right angle with the axis) take hold of the flour contained in the trough 3, and push it gradually on to the respective gutters. Beside the slides, shutting the gutters *u*, *x*, *t*, *v*, *w*, there are in the bottom of the conveyer-trough as many slides as possible, in order to prevent its obstruction during the movement of the conveyer.

In the above-described bolters the pushing of the flour through the perforations of the bolting-cloth is produced in such a manner that the contents of the bolter are during its rotation cast up, and then by their own weight fall upon the under side of the bolter; whereas, in the following rotative bolters (which in all other respects are arranged like the other just mentioned) the bolting is effected by *beaters* or other similar instruments. By this arrangement, the obstruction of the perforations is prevented with more success.

Figs. 482 and 483 represent a bolter of this kind and its hutch in longitudinal and transverse sections; and Figs. 484 and 485 represent the bolter in transverse section, and in a side view. The hexagonal wooden axis is marked by *a a*. From each of its six flat sides project six cylindrical staves *b*, of hard timber, and one inch in diameter, and placed at the distance of two or three feet from each other. The staves of every row are at their points connected with each other by a lath *c*, over which the bolting-cloth is tentered, and to which it is fastened with pins. Upon each staff is put a little tube of cast-iron, 1½ to 2 pounds weight, 3 to 4 inches long, 2 inches in the outer diameter, and called beaters. During the rotation of the bolter, produced by the wheels *e* and *f*, Fig. 482, these beaters run up and down the staves, Fig. 484, and by their beating against the hard-wood supports *g*, Fig. 484, underneath the laths *c*, they prevent the obstruction of the perforations of the bolter. That the laths may not be knocked off by this beating, there are commonly laid round bands either of leather or thin hoop-iron, see *h h*, Fig. 485.

While the lower end of the bolter is left open to let out the grit or bran, the upper end is provided with a wooden crown *i*, Figs. 482 and 483, whose interior diameter leaves only as much room as is required for the plate-iron gutter *k*, Fig. 482, by which the ground mass goes into the bolter. The crown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i is provided with a funnel *l* of tin-plate, for the purpose of retaining the grit or flour within the bolter.

A bolter of this kind is commonly from 16 to 26 feet long, and 24 to 30 inches diameter, and inclines in the ratio of one-fifteenth to one-eighth of its length. Its silk bolting-cloth is selected out of two to five, and even still more numbers. The first sort covers the greatest part of the bolter from above, and then follow in succession the coarser qualities. According to the variety of the flour to be obtained, there are brought into connection with a set of 4 or 5 feet millstones, either one, or two, or more bolters, which are placed in the above manner, (see Figs. 470 and 471.) The most proper arrangement is, that the upper parts of the bolter (covered with the finer sorts of bolting-cloth) furnish the flour at once completely bolted, while the less fine grit of the other parts is to be ground and again bolted.

The different qualities of flour or grit are taken up in separate partitions of the bolting-hutch, of which a simple arrangement is represented by Figs. 482 and 483. The partitions *n* separate the lower part of the bolting-hutch *m m* into the partitions 1, 2, 3, and 4, of which the first three take up three different sorts of flour, while the partition 4 takes up the grit or bran issuing from the mouth of the bolter, and has on its outside a hole (with the slide *o*) through which the grit or bran comes out. The oblique tables *p p*, Fig. 483, leave below an opening from 6 to 12 inches wide, through which the bolted flour falls into the partitions. Each of the latter, 1, 2, and 3, is provided with a valve, consisting of a frame covered with cloth, (see *q*, Fig. 482,) and whose hinges are marked by *r r*. The valve may be kept open by fastening it to the buttons *s s*, Fig. 483.

Another proper arrangement for taking up the flour or grit, is shown by Figs. 486 and 487. Here the bottom *b* of the bolting-hutch *a a*, (which contains the same partitions as the other ones just described,) runs out in a slope sidewise, through which the flour falling from the bolter accumulates at the side-wall *c c*, Fig. 487, and thus runs easily through the opening *d*, into the bag *f*, as soon as the slide *e* is shut up. As many as convenient are placed before a flour-partition, Fig. 486. They are put up and taken away in the following simple manner: At the sack-mouth *i*, beneath the opening *d*, on which rests the sloping bottom *b*, are put in two screws *h h*. Their ends are crooked into hooks which grasp the leather rim *i* of the sack. (See *h* beneath the opening *d*, Fig. 487.) About 3 or 5 feet above each sack projects a rafter *k*, from which hangs down a thong *l*, with forceps *m* and *n*, to take hold of the rim of the sack.

It may be finally remarked, that it has been tried to supplant the beaters above described, (see Fig. 484,) by another contrivance represented by Figs. 488 and 489 in side and front views. The chief part consists of a thick steel button marked *b*, Fig. 488, fixed at the upper pivot of the bolter's axis *b*, Fig. 488. The steel button turns round on a strong and well-polished steel plate *c*, inserted into the pivot-base *d*. Now the axis in turning round is by the three protuberances lifted up and down, and thus constantly kept in a shaking motion. In this way the obstruction of the perforations of the bolting-cloth is prevented as well as by the beaters.

The *brush-bolter*, or cylindrical dressing-machine, as it is styled, is in many mills used conjointly with Ayton's improved bolting-machine, into which latter the grit and bran is brought after they have been bolted in the dressing-machine.

Fig. 475 gives a side view of the common brush-bolter, while Figs. 476 and 477 represent an improved machine of this kind in transverse and longitudinal section, several parts of which are illustrated by Figs. 478 and 479, (on a large scale,) and 480 and 481.

The bolter, both of the common and improved machine, is cylindrical, covered by a bolting-cloth made of wire-texture, and placed obliquely in the bolting-hutch. (See Figs. 475, 476, and 477.) The bolting-cloth in Fig. 475 is directly fixed to the bolting-frame; but in Figs. 476 and 477 it is kept suspended by long screw-bolts *q q*, fixed at the roof of the bolting-hutch. (See Figs. 476, 477, 480, and 481.) The cylindrical sieve-frame of the common machine, Fig. 475, consists of staves *b b*, fixed round the disks *c c* and at the felloes *d*. The interior periphery of this frame is covered with wire-gauze of different fineness—the first number fixed at the upper end, and the less fine sorts following in succession, just in the same way as has been mentioned.

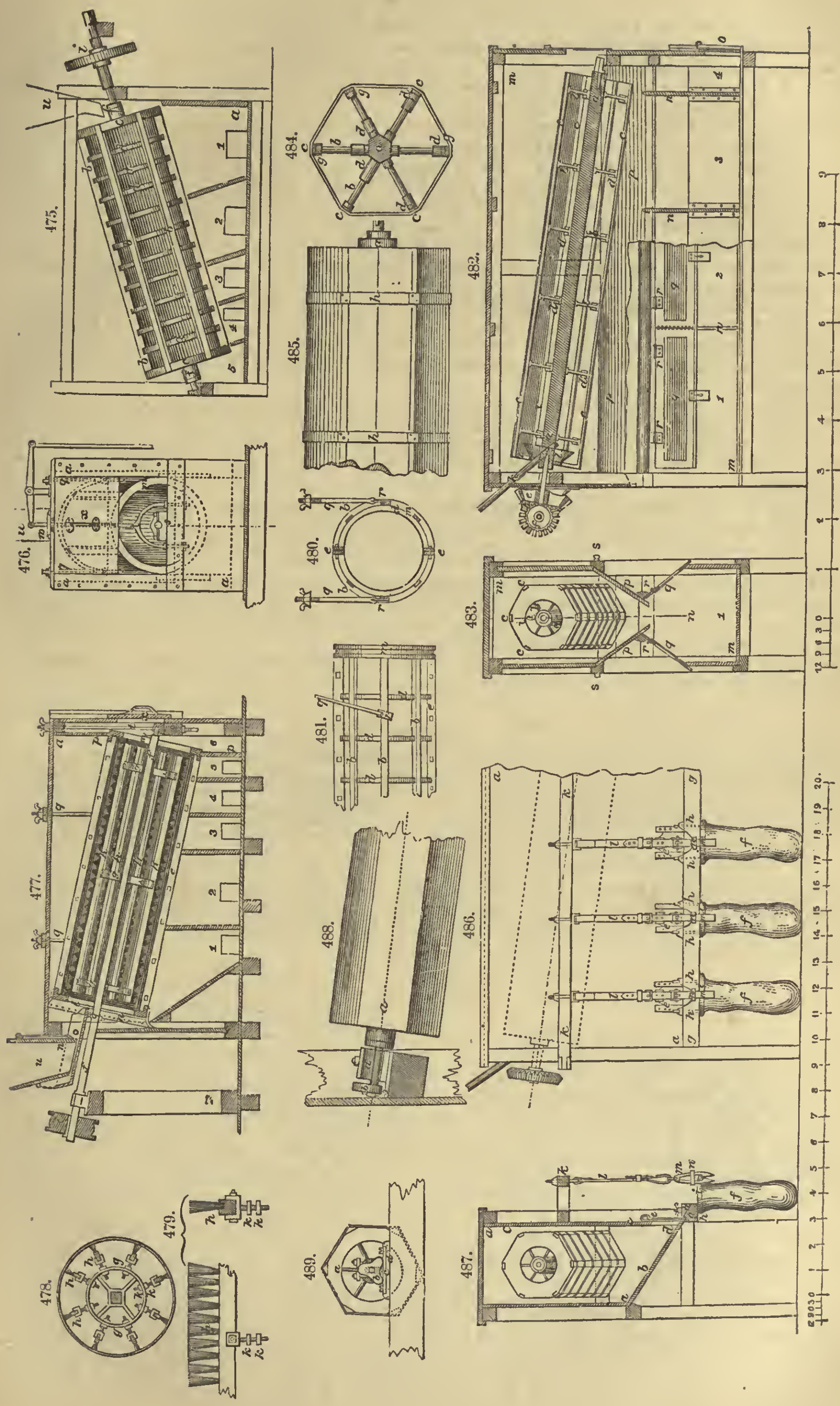
The sieve-frame of the improved machine consists of two semi-cylinders, (see Figs. 477, 480, and 481,) whose side-boards *e e* are laid and screwed together, thus forming a full cylinder.

Within this cylindrical sieve is, exactly in its axis, placed the shaft *f f*, (made of wrought-iron in the machines represented in Figs. 475 and 476,) which is provided with three disk-wheels *g g g*, Fig. 477. On the periphery of these wheels are put in eight brushes of hog's bristles *h*, (see Figs. 478 and 479,) in the manner illustrated, not only by Fig. 477, but also by Fig. 478, where the wheel-periphery is marked by *g g*, and the brushes by *h h;* while the outer circle signifies the inner periphery of the cylindrical sieve. The shaft *f f*, Fig. 477, is turned by the disk *i*, and during its rotation the brushes touch the inner periphery of the cylindrical sieve as much as required, to prevent the obstruction of the perforations by flour. In case the brushes should be worn, they can be screwed more forward by boxes *k k*, Fig. 478.

At the upper and lower end of the cylindrical sieve are the wooden rings *l* and *m*, Fig. 477, fastened by means of screws. They are in the periphery somewhat notched, as may be seen by *m*, Fig. 481 To the upper ring *l*, Fig. 477 is tied, by means of a cord, the leather strip *n*, which is glued or nailed on the bolting-hutch *a a*. By this arrangement the ground mass, coming out by the spout *o*, is taken up here, and conveyed to the cylinder. The ring *m*, at the lower end, serves as a link between the partition-boards *p p*.

In order to establish equality in the brushing of the sieve, this latter, or the cylindrical bolter, is, by means of four screw-bolts *q q*, kept in suspension, and may, according to circumstances, be wound up and lowered, for which purpose the nuts are winged. The screw-bolts are at their ends provided with hooks *r r*, Figs. 480 and 481, which take hold of two side-laths *b b*, Fig. 481, of the cylindrical frame of the sieve. On the other hand the brush-cylinder, whose shaft *f f* rests on the sliding-rail *s*, can also be displaced, either up or down, by the nut of the screw *t*.

The hopper, which holds the ground grain, is marked by *u*, Fig. 477, and the moveable spout con-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nected with it by *o*. This spout is shaken by a nave *v*, fixed at the shaft *ff*, which beats during the rotation against a tack at the bottom of the shoe. By the slide at *w*, the quantity of ground grain in the shoe can be increased or decreased. The slide *x*, which in Fig. 477 is closed, is shut up in Fig. 476.

A cylindrical sieve or bolter of this kind is commonly covered with four or five different numbers of wire-texture, through which the different qualities are bolted, and taken up by the corresponding partitions 1, 2, 3, 4, and 5, whence the flour is easily taken out through the side-openings, until then closed by slides. The bran falls into the partition 6.

The fineness of the texture is commonly in the ratio of 64, 60, 56, 38, and 16 meshes to the square inch. Experience has taught, that the best arrangement is to cover the frame from above, first with gauze or texture of 60 meshes, and to follow in succession that of 64, 56, 38, and 16 meshes. The gauze of 60 meshes furnishes as fine flour as that of 64, which is owing to the circumstance that the flour in the uppermost part of the bolter is not so much exposed to the influence of the brushes, and that the finest quality of flour is more sticky or viscous than the coarser qualities.

By the rotation in one and the same direction, the bristles of the brushes must at last be bent to one side, and thus lose their efficacy. To remedy this, an arrangement is made by which the brush-reel turns alternately to the right and left. This is easily effected by double wheels or thong-disks.

A small brush-cylinder has been invented by James Murphy, of Zanesville, O., which is to be placed at the outside of the above-described cylindrical sieve, that is, everywhere on its periphery brushed by it. By this operation the obstruction of the meshes is completely prevented. Mr. Murphy uses thin hoops and ribs of cast-iron for constructing the sieve-frames, instead of the above-described wooden felloes and laths.

BOLTS, (*iron.*) The pieces of iron used for securing framing together, and much employed in timber work; they are formed of wrought-iron, either square or cylindrical, with a square head at one end, and a screw and nut at the other; a plate of iron, termed a *washer*, being interposed between the surface of the wood and the head and nut, to protect the former from damage during the process of screwing up.

BOLSTERS. The pieces of timber used in the construction of the centres of arches, and running across from one rib to another, for the purpose of supporting the voussoirs. A piece of timber, employed in a somewhat similar manner to a corbel, is also termed a *bolster;* which are much employed in timber bridges.

BOND. The union or tie of the several stones or bricks forming a wall. The great principle in all bond is to provide against settlements: the vertical joints of a course should, therefore, be exactly midway between those below—in other words, *break joint* with them; and in no case should the joints of one course be carried up over those of the one below it.

The bricks or stones lying lengthwise, in the longitudinal direction of the wall, are called *stretchers*, and those placed lengthwise across the wall, *headers*.

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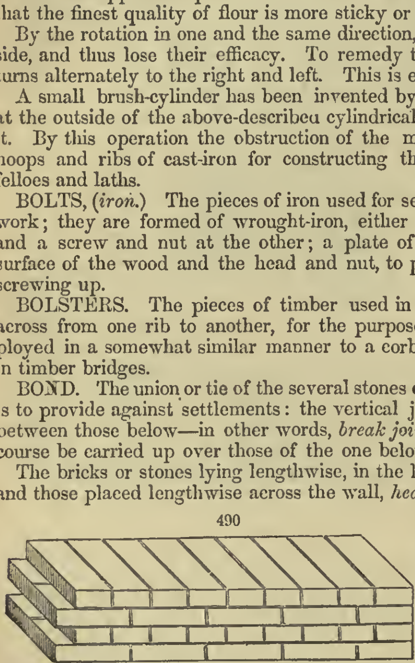

Old English Bond, or Block-bond.

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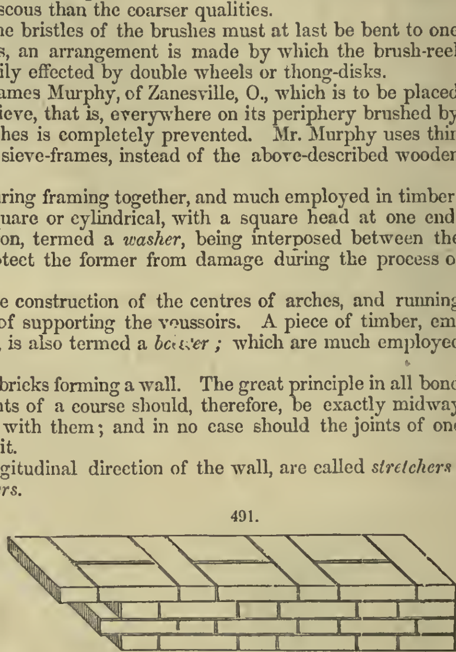
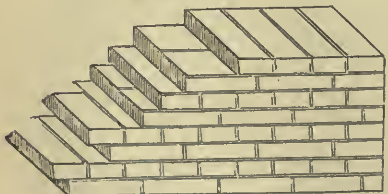


Flemish Bond.

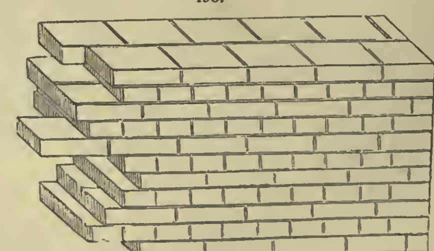
Bond may be described generally to be of three kinds. In English bond the courses are alternately all headers and all stretchers, and when the backs of each course are laid alternately header and stretcher it is called Flemish Bond; this description of tie is also known by the name of *header and stretcher* particularly in stone-work.

492.



Cross-bond.

493.



Combined Cross and Block bond.

The *cross-bond*—mostly used in Germany by bricklayers—differs from the old English or block bond, by the change of the second stretcher-line, so that the joints of the second come in the middle of the first, and the same position of stretchers comes back only every fifth line. This bond gives besides a very neat appearance, and is therefore used wherever a nice building is to be erected. The strongest tie is given to a wall by combining the block and cross-bond, so that the extrados is put up in cross-bond, the intrados in block-bond, as shown in the figure. The reason of it is, if a settling of the wall happens, so that the joints open, all other bonds give only in the vertical, a crooked breaking line; but this combined-bond requires a crooked breaking-line in the horizontal direction besides; it is therefore applied where a neat appearance and great strength are required.

BONES. See ANIMAL KINGDOM, *materials from used in the mechanical and ornamental arts.*

BORING MACHINE, *Vertical:* by Messrs. Nasmyth, Gaskell & Co. The many advantages derived by this arrangement of a vertical boring machine over those where the work is placed in a horizontal position, may perhaps be unknown to persons unacquainted with the general character of machinery; it may not be unadvisable to point out a few of the principal features showing the superiority of this machine.

In the first place, the arrangements of its parts; the manner in which the cylinder is placed, namely, its vertical position, thereby doing away entirely with all the injurious effects produced by the weight of the body being planed or bored; thus obviating all tendency to distort its figure, which is the case where the operation is performed by the horizontal system, and where the sides are bulged out from the weight of the upper part; this may be better understood by forming a cylinder of thin paper, which will be found to widen in the middle and assume an oval form from its own weight.

This alteration of form is found to be quite sensible when the cylinders are of large diameters. Another great advantage of this system of vertical boring, is avoiding all risk of flexure in the boring-bar, upon which the cutter wheel or head is fixed for carrying the boring-tools; this bar has a tendency to bend down in the centre to a curve, instead of keeping a perfectly straight line, transferring the figure assumed by the bar to the surface of the cylinder; but this will much depend both on its length and diameter.

Another advantage of this machine is, that the cutters are kept clear of the borings, which fall to the bottom of the cylinder as fast as they are cut. By this superior arrangement all these objections are entirely removed, thus avoiding all the tendency gravity has in altering the trueness of the cylinder or the bar; added to these, the power requisite to bore the cylinder is found to be much less than in those placed horizontally, a very desirable object in a large establishment.

A short description of its several parts will enable the reader more fully to understand the advantages already alluded to.

Fig. 494 represents a cross-section of this machine, and Fig. 497 a plan showing its position in a corner of the building where it is placed. In these two views it will be seen that the driving part of the machinery is situated below the ground-line on suitably strong foundations, in which it is enclosed. These parts are rendered accessible by the steps *t*, which are found to be necessary in cases where the machinery is likely to get out of order, a precaution never to be neglected.

The two riggers *k k* receive their motion from the main shaft by means of a leather strap: one of these runs loose on the shaft, and the strap is thrown on it when the machine is not at work; this is done at pleasure with the greatest possible facility; by a bevel-wheel and pinion *j*, it is then conveyed through the shaft *i* to the endless worm *n*, working in a large worm-wheel *o*, which is fixed on the great vertical boring-bar *a*, whereby a very easy motion is obtained, and all jerks avoided. It will be seen by the series of wheels in Fig. 497, how much the speed of the boring-bar is reduced. The shaft *i* is placed at an angle, and works in a bearing or plummer block and a step *h*, both of these being made of brass.

The vertical bar is made in two parts *a* and *c*, the upper one *a* for carrying the cutter-head or boring-wheel *r*, while to the lower one is connected the driving apparatus; they are coupled together by the upper one resting, as is shown in Fig. 496, in a socket on the top of the lower one; a steel key *l* is then driven in, which entirely prevents it from turning; the toe of the bar *c* rests in a step or socket shown by Fig. 498; the entire weight of this bar and its appendages is thrown on the hardened cast-steel disks *s*, which are constantly kept supplied with oil. Both extremities of the bar *c* are rendered adjustable to the greatest possible accuracy by means of the small set-screws *q q*, Figs. 496 and 498, which, by being tightened, press against the conical brass segments, the upper one forming part of the great base or floor-plate *b*, which is materially strengthened by six strong ribs on its under side. The cross-beam *g* is well fitted to the sockets *f*, built into the wall of the building, where they are bolted by strong bolts, Figs. 494, 495, and 497. It has an additional stay in the bolt *u*.

There are four standards or supports, *d d*, Fig. 494, for carrying the cylinder to be bored, which can be altered to any convenient position by unscrewing the bolts which fix them to the base-plate. After the cylinder has been properly placed in its right position, it is fixed to these supports by clamps *e* and bolts; and thus rendered quite immoveable.

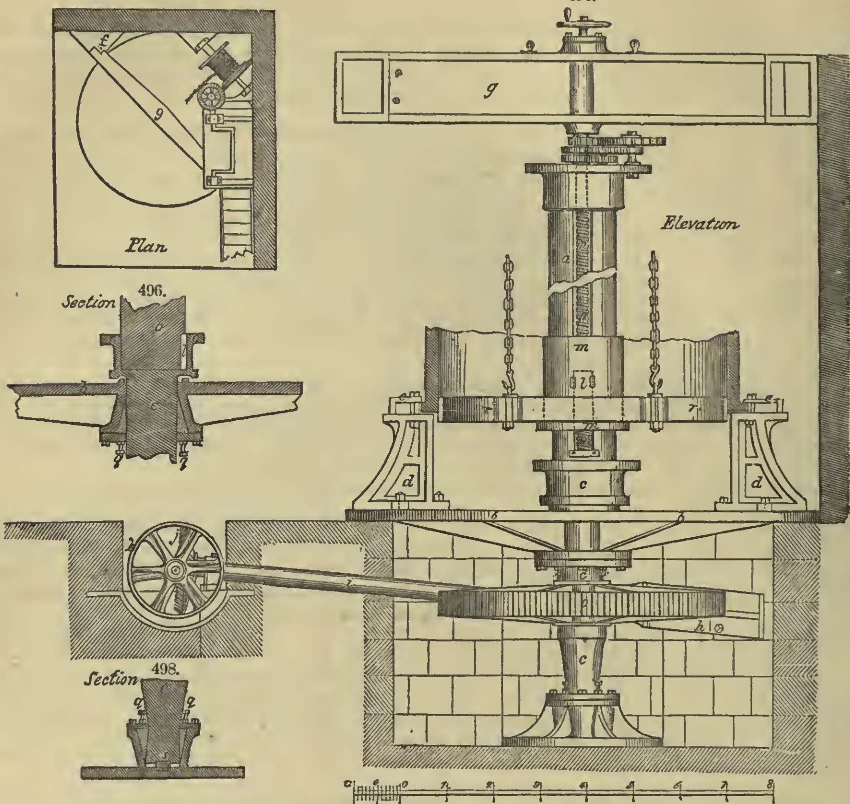
In the boring-bar *a* is a deep socket *m*, Fig. 494, which allows the bar to slide up and down by means of the screw *p* and the nut *l*; upon the lower side of this socket is a flange *m*, upon which the cutter-head or wheel *r* rests, receiving its motion from the bar by means of a nut, answering both the purpose of nut and key. By the different arrangements of the sun and planet motion of the wheels on the upper part of the bar, any degree of motion can be given to the screw for the descent of the cutter-wheel. After the cylinder has been once bored through, the cutter-wheel is raised by means of a small crane, and the chains, Fig. 495, and by the peculiar arrangement of the nut *l* in the socket *m*, the cutter-wheel can be drawn up the cylinder without turning the screw *p*, as it leaves the nut behind, which is afterwards screwed up, there being no other weight to raise but that of the nut. The cutters are then set afresh to the new or finishing cut, after which the cylinder may be considered perfectly true. The position occupied by the crane enables the cylinder to be placed, and the bar lifted in and out with most perfect ease; while the space occupied by this machine is very small compared with those where the work is performed horizontally; it is, however, important that the base-plate *b* should be well secured to the foundations by strong bolts.

The speed of this machine may very easily be varied, by having different-sized riggers or pulleys on the driving-shaft which conveys the motion to the riggers *k k*, Figs. 494 and 497.

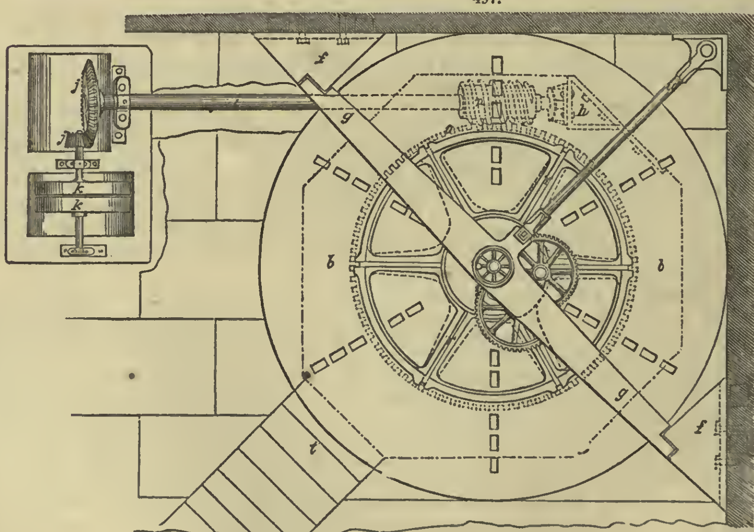
BORING MACHINE, *Great.* By Messrs. Nasmyth, Gaskell and Co. The machine represented by Fig. 499 is, with few exceptions, the same as that last described, where the cylinder to be bored is placed in a vertical position, whereby numerous advantages are derived, as already explained.

The motion is communicated by the driving-pulley *c* to a bevel pinion working the bevel wheel *d*

495. 494.



497.



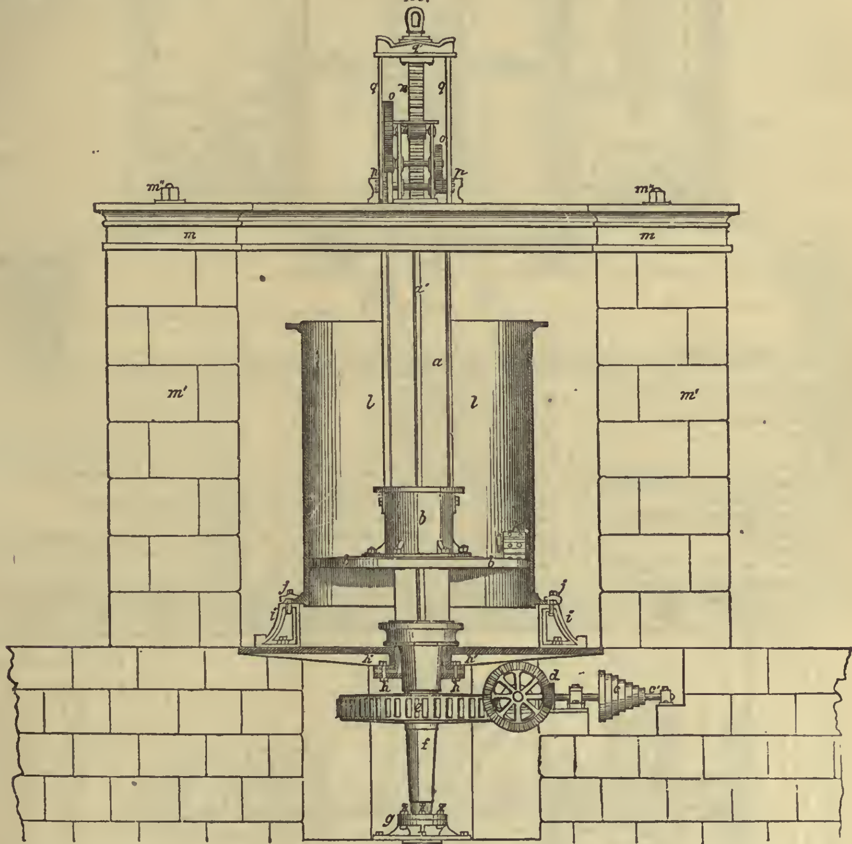
a Boring-bar.
b Foundation or base plate.
c Socket and lower part of upright bar.
d Moveable supports for carrying cylinder to be bored.
e Clamps.
f Socket for carrying the beam *g*.
g Cross-beam.
h Step or bearing for driving-shaft.
i Driving-shaft.
j Bevel-wheel and pinion.
k Driving riggers.
l Keys and nut.
m Socket upon which the cutter-wheel rests.
n Screw working in wheel *o*.
o Screw-wheel.
p Screw for regulating drilling-bar.
q Adjusting-screws.
r Boring-wheel.
s Steel disks or pivots
t Steps.
u Tie bar.

the shaft on which this wheel is fixed, has on its opposite end a worm for communicating the motion through the worm-wheel to the upright shaft *f* and boring-bar *a*, having on its circumference the grooves *a'* in which the cutter-head is moveable, sliding up and down according to the progress of the work; *k* is a tool-carrier fixed to the cutter-head. The foundation plate *h* forms a bearing for the upright shaft, the lower end of which rests in the step *g*, while the cylinder *l* is secured by the clamps *j j* to the supports *i i* fixed to the foundation plate. These parts are in every respect similar to the boring machine shown by Fig. 494, by which they are more fully described.

Two strong piers of masonry *m'* support the entablature *m*, (for carrying the self-acting apparatus for raising and lowering the cutter-head *b*,) to which it is bolted by strong holding-down bolts *m''*. This apparatus consists of a rack *n* worked by a pinion, the motion being transmitted from a trullion-wheel through two spur-wheels and pinions *o*. The whole of this upper machinery revolves with the boring-bar, with the exception of the internal wheel or screwed hoop *p*; the consequence of which is, the small trullion-wheel is made to turn on its axis by the thread of the wheel *p* in which it works, and thereby ultimately raises the cutter-head *b*, the two side-slings connecting it to the upper frame *q'*, to which is fixed the rack *n*.

This machine is of the largest dimensions, and was made for the purpose of boring the large cylinders, 10 feet in diameter, for the Great Western Steam Navigation Company's vessel the Mammoth, at their works at Bristol.

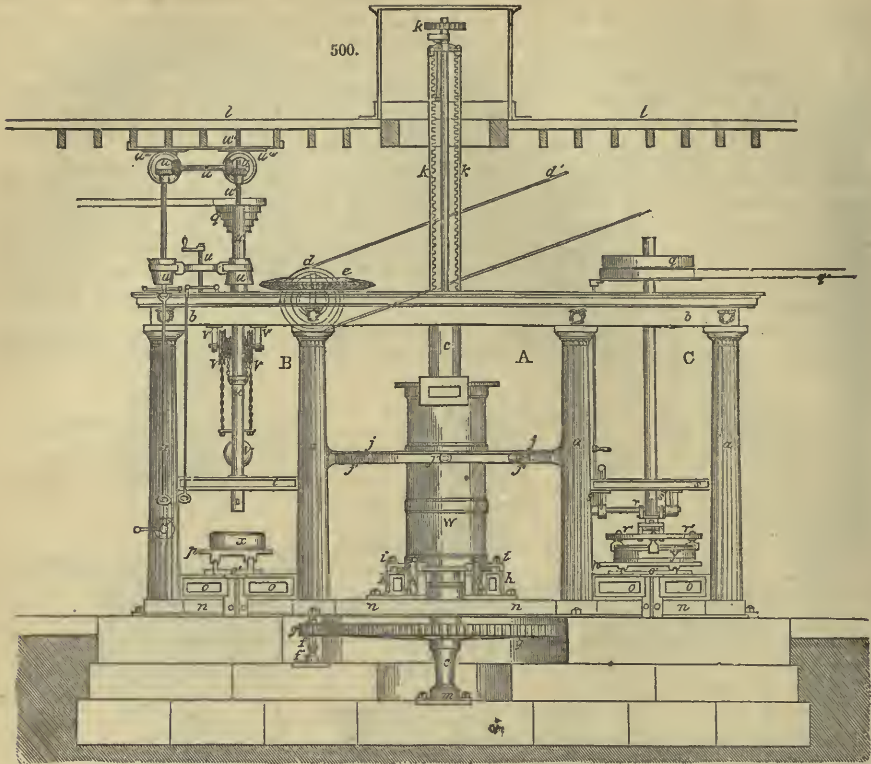
499.



a Upright boring-bar.
b Cutter-head working up and down in the three V's *a'*.
c Driving-pulleys fixed on shaft *c'*.
d Bevel-wheel and pinion for conveying the motion at right angles.
e Worm-wheel.
f Upright shaft for working boring-bar.
g Step for shaft.
h Foundation plate and boring-box bearing, tightened by conical pieces and screws *h*.
i Supports for carrying the cylinder to be bored.
j Clamps for fixing cylinder to supports *i*.
k Tool-carrier fixed to cutter-head.
l Cylinder being bored.
m Entablature for guiding the upper part of bar, bolted to walls *m'* by bolts *m''*.
n Rack and pinion for raising the cutter-head, worked by spur-wheels and pinions *o*.
o Spur-wheels and pinions.
p Internal screw-wheel on the upper part of cutter-head conveying the self-acting raising motion to it, by the trullion-wheel and spur-wheels and pinions *o*.
q Side-slings which convey the elevating or cut-feeding motion from the rack *n* down to the cutter-head *b*. All revolves with the boring-bar except the internal screw-wheel or screwed hoop *p*, which is stationary, being bolted to the entablature.

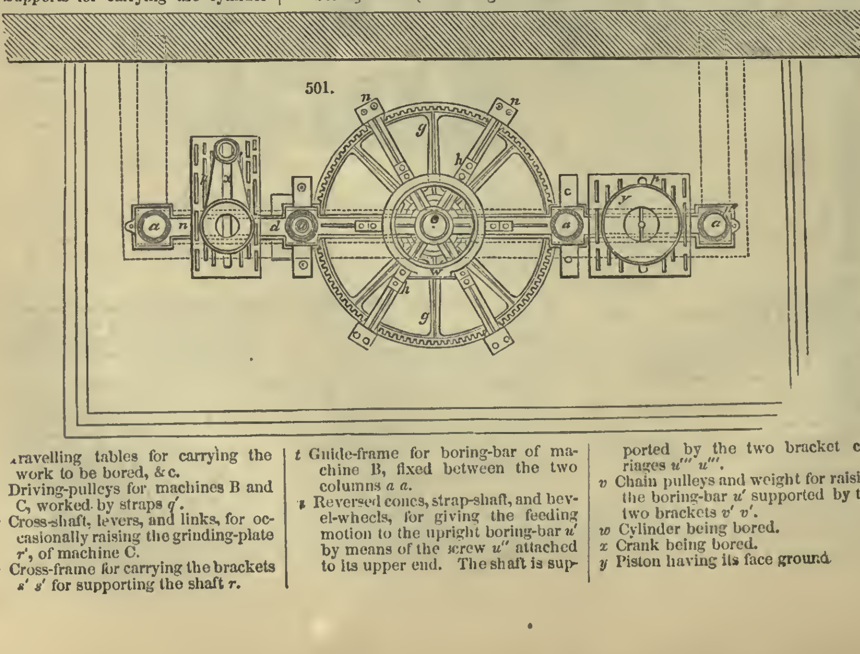
BORING MACHINE, *Vertical*. By Messrs. Benjamin Hick and Son, Bolton. By this combination of three distinct machines, the following different operations may be performed, viz. boring, drilling, and face-grinding: it is so contrived that the entablature *b*, supported by the four columns *a a a a*, carries

500.



a Columns for supporting the entablature *b*.
b Entablature.
c Boring-bar of large machine.
d Driving-pulleys worked by leather strap *d'*.
e Bevel-wheel and pinion conveying the motion to the upright shaft *f* through the column *a*.
f Upright shaft working in footstep *f'*.
g Spur pinion and wheel for working the boring-bar *c*.
h Supports for carrying the cylinder to be bored moveable in grooves in the foundation plate *n*.
i Clamps or Caps for securing the cylinder to the supports *h*.
j Circular frame or ring for steadying the cylinder, which is adjusted to its proper place by the set-screws *j'*: this frame can be raised or lowered, and is secured by bolts fitted into grooves in the back of columns *a*.
k Racks and wheels attached to the boring-block (containing the steel cutters) for giving it the feed or advancing motion.
l Second floor of the building, and on which is placed a crane for raising or lowering the boring-bar when a cylinder has to be placed or removed.
m Footstep for boring-bar.
n Foundation plate.
o Framing and beds of the side machines on which the V slides *o'* move.

501.



p Travelling tables for carrying the work to be bored, &c.
q Driving-pulleys for machines B and C, worked by straps *q'*.
r Cross-shaft, levers, and links, for occasionally raising the grinding-plate *r'*, of machine C.
s Cross-frame for carrying the brackets *s' s'* for supporting the shaft *r*.
t Guide-frame for boring-bar of machine B, fixed between the two columns *a a*.
u Reversed cones, strap-shaft, and bevel-wheels, for giving the feeding motion to the upright boring-bar *u'* by means of the screw *u''* attached to its upper end. The shaft is supported by the two bracket carriages *u''' u'''*.
v Chain pulleys and weight for raising the boring-bar *u'* supported by the two brackets *v' v'*.
w Cylinder being bored.
x Crank being bored.
y Piston having its face ground.

the upper parts of the three different machines, consisting of the requisite driving machinery for communicating to them their respective motions.

That in the centre, A, is a vertical boring machine for boring cylinders of large diameters, which are fixed in the usual way on the six moveable supports h by the clamps i; in addition to which it is rendered perfectly steady by the circular frame or ring j, sliding up and down in grooves on the back of the two middle columns, the adjusting-screws j being tightened when the cylinder is properly placed under the centre of the boring-bar c, which receives its motion from the leather strap and pulleys d, whence it is conveyed through the bevel pinion and wheel e on the upright shaft f, upon which is also keyed the spur-pinion for driving the wheel g fixed to the lower part of the boring-bar c, and working in the step m; the rack and wheel k gives the cutter-head the requisite feed while boring out the cylinder. The six supports h are made to slide in grooves on the foundation plate n, according to the different diameters of the cylinders being operated upon; these, when properly placed, are bolted to the plate n.

The second machine, B, is a vertical drilling and boring machine for work of smaller dimensions than the machine A. It is shown in the drawing boring out the centre of a crank x, fixed to the travelling table p, and slides on V's on the frame o', which has also a motion at right angles, on the bed o fixed to the foundation plate. The drilling-bar u' is lowered by the screw u'' according to the feed, its motion being conveyed to it from the pulley q and strap q' to a spur-wheel and pinion not shown in the drawing; the pinion is on the same spindle as the pulley, and the wheel on that of the reversed cone u, by which it is carried to the square-threaded screw u'' by two pairs of small bevel-wheels u, fixed on a horizontal spindle and working in suitable bearings on the carriages u''' u'''. The apparatus for raising the drilling-bar, Fig. 500, consists simply of two small chains fixed to the bar u' and working round the pulleys, its opposite end being attached to a weight v.

The third machine C, is for the purpose of grinding up the faces of rings for metallic pistons, conical valves, &c.; the travelling table p of this machine is in every respect similar to that of B, and upon it is placed the piston y to be ground; the upright rod, receiving its motion from the pulley and strap q', is kept in a vertical position by the cross-frame s, while the shaft r and grinding-plate are connected to the lower end of the rod, and are occasionally raised for examining the surface being ground.

The different motions given to these machines are quite independent the one of the other, by which means any one of them can be worked separately. The whole is placed on a suitable strong foundation of stone. After the large cylinder is bored, it is raised from its position by a crane placed on the floor above.

BORING MACHINES, for cannon. See CANNON.

BORING FOR WELLS, and Tools therefor. See ARTESIAN WELLS.

BORING TOOLS.* The process of boring holes may be viewed as an inversion of that of turning; generally the work remains at rest, and the tool is revolved and advanced. Many of the boring and drilling tools have angular points, which serve alike for the removal of the material, and the guidance of the instrument; others have blunt guides of various kinds for directing them, whilst the cutting is performed by the end of the tool.

Commencing as usual with the tools for wood, the brad-awl, Fig. 502, may be noticed as the most simple of its kind; it is a cylindrical wire with a chisel edge, which rather displaces than removes the material; it is sometimes sharpened with three facets as a triangular prism. The awl, Fig. 503, used by the wire-workers, is less disposed to split the wood; it is square and sharp on all four edges, and tapers off very gradually until near the point, where the sides meet rather more abruptly.

The generality of the boring instruments used in carpentry are fluted, like reeds split in two parts, to give room for the shavings, and they are sharpened in various ways, as shown by Figs. 504 to 508. Fig. 504 is known as the *shell-bit*, and also as the *gouge-bit*, or *quill-bit*; it is sharpened at the end like a gouge, and when revolved it shears the fibres around the margin of the hole, and removes the wood almost as a solid core. The shell-bits are in very general use, and when made very small, they are used for boring the holes in some brushes.

502. 503. 504. 505. 506. 507. 508.

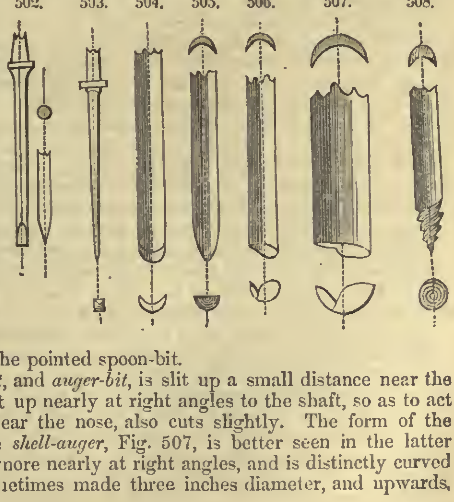


Fig. 505, the *spoon-bit*, is generally bent up at the end to make a taper point, terminating on the diametrical line; it acts something after the manner of a common pointed drill, except that it possesses the keen edge suitable for wood. The spoon-bit is in very common use; the *coopers' dowel-bit*, and the *table-bit*, for making the holes for the wooden joints of tables, are of this kind. Occasionally the end is bent in a semicircular form; such are called *duck-nose-bits* from their resemblance, and also *brush-bits* from their use; the diameter of the hole continues undiminished for a greater depth than with the pointed spoon-bit.

The *nose-bit*, Fig. 506, called also the *slit-nose-bit*, and *auger-bit*, is slit up a small distance near the centre, and the larger piece of the end is then bent up nearly at right angles to the shaft, so as to act like a paring-chisel; and the corner of the reed, near the nose, also cuts slightly. The form of the nose-bit, which is very nearly a diminutive of the *shell-auger*, Fig. 507, is better seen in the latter instrument, in which the transverse cutter lies still more nearly at right angles, and is distinctly curved on the edge instead of radial. The augers are sometimes made three inches diameter, and upwards,

* Holtzapffel's Turning and Mechanical Manipulation.

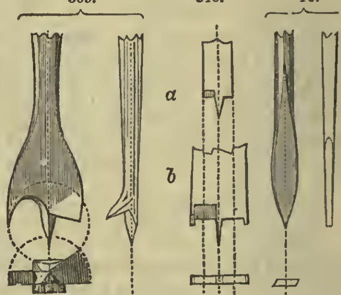
and with long removeable shanks, for the purpose of boring wooden pump-barrels; they are then called *pump-bits.*

There is some little uncertainty of the nose-bits entering exactly at any required spot, unless a small commencement is previously made with another instrument, as a spoon-bit, a gouge, a brad-awl, a centre-punch, or some other tool; with augers a preparatory hole is invariably made, either with a gouge, or with a centre-bit exactly of the size of the auger. When the nose-bits are used for making the holes in sash bars, for the wooden pins or dowels, the bit is made exactly parallel, and it has a square brass socket which fits the bit; so that the work and socket being fixed in their respective situations, the *guide-principle* is perfectly applied. A "*guide-tube*" built up as a tripod, which the workman steadies with his foot, has been recently applied by Mr. Charles May, of Ipswich, for boring the auger-holes in railway sleepers exactly perpendicular.

The gimlet, Fig. 508, is also a fluted tool, but it terminates in a sharp worm or screw, beginning as a point and extending to the full diameter of the tool, which is drawn by the screw into the wood. The principal part of the cutting is done by the angular corner intermediate between the worm and shell, which acts much like the auger. The gimlet is worked until the shell is full of wood, when it is unwound and withdrawn to empty it.

The centre-bit, Fig. 509, shown in three views, is a very beautiful instrument; it consists of three parts, a centre-point or *pin*, filed triangularly, which serves as a guide for position; a thin shearing-point or *nicker*, that cuts through the fibres like the point of a knife; and a broad chisel-edge or *cutter*, placed obliquely to pare up the wood within the circle marked out by the point. The cutter should have both a little less radius and less length than the nicker, upon the keen edge of which last the correct action of the tool principally depends.

509. 510. 11.

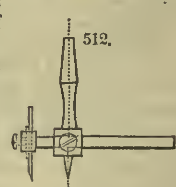


Many variations are made from the ordinary centre-bit, Fig. 509; sometimes the centre-point is enlarged into a stout cylindrical plug, so that it may exactly fill a hole previously made, and cut out a cylindrical countersink around the same, as for the head of a screw-bolt. This tool, known as the *plug centre-bit*, is much used in making frames and furniture, held together by screw-bolts. Similar tools, but with loose cutters inserted in a diametrical mortise, in a stout shaft, are also used in ship-building for inlaying the heads of bolts and washers, in the timbers and planking.

The *wine-cooper's centre-bit* is very short, and is enlarged behind into a cone, so that immediately a full cask has been bored, the cone plugs up the hole until the tap is inserted. The centre-bit deprived of its chisel-edge, or possessing only the pin and nicker, is called a *button-tool;* it is used for boring and cutting out, at one process, the little leather disks or *buttons*, which serve as nuts for the screwed wires in the mechanism connected with the keys of the organ and pianoforte.

The *expanding centre-bit*, shown on a much smaller scale in Fig. 512, is a very useful instrument; it has a central stem with a conical point, and across the end of the stem is fitted a transverse bar adjustable for radius. When the latter carries only a lancet-shaped cutter it is used for making the margins of circular recesses, and also for cutting out disks of wood and thin materials generally; when, as in Mr. James Stone's modification, the expanding centre-bit has two shearing-points or nickers, and one chisel-formed cutter, it serves for making grooves for inlaying rings of metal or wood in cabinet-work, and other purposes.

512.



The above tools being generally used for woods of the softer kinds, and the plankway of the grain, the shearing-point and oblique chisel of the centre-bit, Fig. 509, are constantly retained, but the corresponding tools used for the hard woods assume the characters of the hard-wood tools generally. For instance, *a*, Fig. 510, has a square point, also two cutting edges, which are nearly diametrical, and sharpened with a single chamfer at about 60 degrees; this is the ordinary *drill* used for boring the finger-holes in flutes and clarionets, which are afterwards chamfered on the inner side with a stout knife, the edge of which measures about 50 degrees. The key-holes are first scored with the *cup-key tool*, *b*, and then drilled, the tools *a* and *b* being represented of corresponding sizes, and forming between them the annular ridge which indents the leather of the valve or key.

When *a*, Fig. 510, is made exactly parallel and sharpened up the sides, it cuts hard mahogany very cleanly in all directions of the grain, and is used for drilling the various holes in the small machinery of pianofortes; this drill (and also the last two) is put in motion in the lathe; and in Fig. 511, the lathe-drill for hard woods, called by the French *langue de carpe*, the centre-point and the two sides melt into an easy curve, which is sharpened all the way round and a little beyond its largest part.

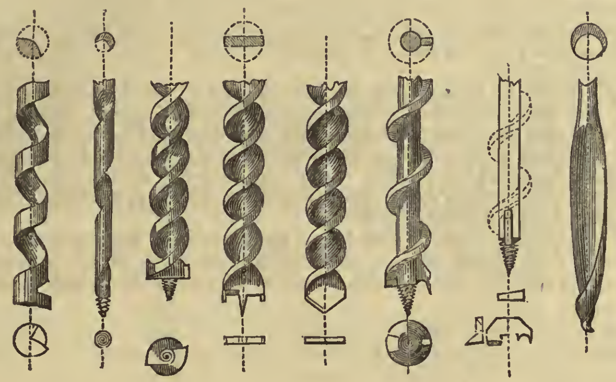
Various tools for boring wood have been made with spiral stems, in order that the shavings may be enabled to ascend the hollow worm, and thereby save the trouble of so frequently withdrawing the bit. For example, the shaft of Fig. 513, the *single-lip auger*, is forged as a half-round bar, nearly as in the section above; it is then coiled into an open spiral with the flat side outwards, to constitute the cylindrical surface, and the end is formed almost the same as that of the shell-auger, Fig. 507. The *twisted gimlet*, Fig. 514, is made with a conical shaft, around which is filed a half-round groove, the one edge of which becomes thereby sharpened, so as gradually to enlarge the hole after the first penetration of the worm, which, from being smaller than in the common gimlet, acts with less risk of splitting.

The ordinary screw-auger, Fig. 515, is forged as a parallel blade of steel, (seen in Fig. 516, which also refers to 515 and 517;) it is twisted red-hot, the end terminates in a worm by which the auger is

gradually drawn into the work, as in the gimlet, and the two angles or lips are sharpened to cut at the extreme ends, and a little up the sides also.

The same kind of shaft is sometimes made as in Fig. 516, with a plain conical point, with two scoring cutters and two chisel edges, which receive their obliquity from the slope of the worm: it is as it were a double centre-bit, or one with two lips grafted on a spiral shaft. The same shaft has been also made, as in Fig. 517, with a common drill-point, and proposed for metal, but this seems scarcely called for;

513. 514. 515. 516. 517. 518. 519. 520.



but it is in this form very effective in Hunter's patent stone-boring machine, intended for stones not harder than sandstones; the drill is worked by a cross, guided by a tube, and forced in by a screw cut upon the shaft carrying the drill; so that the stone is not ground to powder, but cast off in flakes with very little injury to the drill.

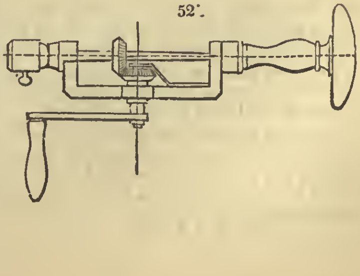
Another screw-auger, which is perhaps the most general after the double-lipped screw-auger, Fig 515, is known as the *American screw-auger*, and is shown in Fig. 518; this has a cylindrical shaft, around which is brazed a single fin or rib; the end is filed into a worm as usual, and immediately behind the worm a small diametrical mortise is formed for the reception of a detached cutter, which exactly resembles the nicking-point and chisel-edge of the centre-bit; it may be called a centre-bit for deep holes. The parts are shown detached in Fig. 519. The loose cutter is kept central by its square notch, embracing the central shaft of the auger; it is fixed by a wedge driven in behind, and the chisel-edge rests against the spiral worm. Spare cutters are added in case of accident, and should the screw be broken off, a new screw and mortise may be made by depriving the instrument of so much of its length. This instrument will be found on trial extremely effective; and on account of the great space allowed for the shavings, they are delivered perfectly, until the worm is buried a small distance beneath the surface of the hole.

The Americans have also invented an auger, thoroughly applicable to producing square holes, and those of other forms: the tool consists of a steel tube, of the width of the hole, the end of the tube is sharpened from within, with the corners in advance, or with four hollowed edges. In the centre of the square tube works a screw-auger, the thread of which projects a little beyond the end of the tube, so as first to penetrate the wood, and then to drag after it the sheath, and thus complete the hole at one process; the removed shavings making their escape up the worm and through the tube. For boring long mortises, two or more square augers are to be placed side by side, but they must necessarily be worked one at a time. The tools Figs. 513 to 520 are American.

The screw-auger acts as a hollow taper-bit or rimmer, and the screw-form point and shaft assist in drawing it into the wood; but the instrument must pass entirely through for making cylindrical holes.

The most usual of the modes of giving motion to the various kinds of boring bits, is by the ordinary carpenter's brace with a crank-formed shaft. The instrument is made in wood or metal, and at the one extremity has a metal socket called the *pad*, with a taper square hole, and a spring catch used for retaining the drills in the brace when they are withdrawn from the work; and at the other it has a swivelled head or shield, which is pressed forward horizontally by the chest of the workman; or when used vertically, by the left hand, which is then commonly placed against the forehead.

521.



The ordinary carpenter's brace is too familiarly known to require further description, but it sometimes happens, that in corners and other places there is not room to swing round the handle; the *angle brace*, Fig. 521, is then convenient. It is made entirely of metal, with a pair of bevel pinions, and a winch-handle that is placed on the axis of one of these, at various distances from the centre, according to the power or velocity required. Sometimes the bevel-wheel attached to the winch handle is three or four times the diameter of the pinion on the drill; this gives greater speed, but less power.

The augers, which from their increased size require more power, are moved by transverse handles some augers are made with *shanks*, and are riveted into the handles just like the gimlet; occasionally the handle has a socket or pad, for receiving several augers, but the most common mode is to form the end of the shaft into a ring or eye, through which the transverse handle is tightly driven. The brad-awls, and occasionally the other tools requiring but slight force, are fitted in straight handles; many of the smaller tools are attached to the lathe-mandrel by means of chucks, and the work is pressed against them, either by the hand, or by a screw, a slide, or other contrivance; Figs. 510 and 511 are always thus applied.

Drills for metal, used by hand.—The frequent necessity in metal works, for the operation of drilling holes, which are required of all sizes and various degrees of accuracy, has led to so very great a variety of modes of performing the process, that it is difficult to arrange with much order the more important of these methods and apparatus.

The ordinary piercing drills for metal do not present quite so much variety as the wood drills recently described. The drills for metal are mostly pointed; they consequently make conical holes, which cause the point of the drill to pursue the original line, and eventually to produce the cylindrical hole. The comparative feebleness of the drill-bow limits the size of the drills employed with it to about one-quarter of an inch in diameter; but as some of the tools used with the bow, agree in kind with those of much larger dimensions, it will be convenient to consider as one group, the forms of the edges of those drills which cut when moved in *either* direction.

Figs. 522, 523, and 524, represent, of their largest sizes, the usual forms of drills proper for the reciprocating motion of the drill-bow, because their cutting edges being situated on the line of the axis, and chamfered on each side, they cut, or rather *scrape*, with equal facility in both directions of motion.

522. 523. 524. 525. 526. 527.

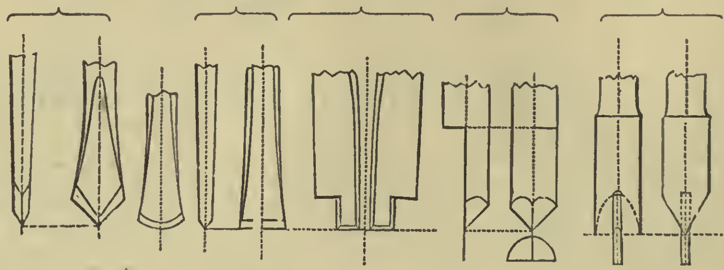


Fig. 522 is the ordinary double-cutting drill; the two facets forming each edge meet at an angle of about 50 to 70 degrees, and the two edges forming the point meet at about 80 to 100; but the watch-makers, who constantly employ this kind of drill, sometimes make the end as obtuse as an angle of about 120 degrees; the point does not then protrude through their thin works, long before the completion of the hole. Fig. 523, with two circular chamfers, bores cast-iron more rapidly than any other reciprocating drill, but it requires an entry to be first made with a pointed drill; by some, this kind is also preferred for wrought-iron and steel. The flat-ended drill, Fig. 524, is used for flattening the bottoms of holes. Fig. 525 is a duplex expanding drill, used by the cutlers for inlaying the little plates of metal in knife-handles; the ends are drawn full size.

Fig. 526 is also a double-cutting drill; the cylindrical wire is filed to the diametrical line, and the end is formed with two facets. This tool has the advantage of retaining the same diameter when it is sharpened; it is sometimes called the Swiss drill, and was employed by M. Le Rivière, for making the numerous small holes in the delicate punching machinery for manufacturing perforated sheets of metal and pasteboard; these drills are sometimes made either semicircular or flat at the extremity, and as they are commonly employed in the lathe, they will be hereafter further noticed.

The square countersink, Fig. 527, is also used with the drill-bow; it is made cylindrical, and pierced for the reception of a small central pin, after which it is sharpened to a chisel-edge, as shown. This countersink is in some measure a diminutive of the pin-drills, Figs. 534 to 537, and occasionally circular collars are fitted on the pin for its temporary enlargement, or around the larger part to serve as a stop, and limit the depth to which the countersink is allowed to penetrate, for inlaying the heads of screws. The pin is removed when the instrument is sharpened.

By way of comparison with the double-cutting drills, the ordinary forms of those which only cut in *one* direction, are shown in Figs. 528, 529, and 530. Fig. 528 is the common single-cutting drill, for the drill-bow, brace, and lathe; the point, as usual, is nearly a rectangle, but is formed by only two facets, which meet the sides at about 80° to 85°; and therefore lie very nearly in contact with the extremity of the hole operated upon, thus strictly agreeing with the form of the turning tools for brass. Fig. 529 is a similar drill, particularly suitable for horn, tortoise-shell, and substances liable to agglutinate and clog the drill; the chamfers are rather more acute, and are continued around the edge behind its largest diameter, so that if needful, the drill may also cut its way *out* of the hole.

Fig. 530, although never used with the drill-bow, nor of so small a size as in the wood-cut, is added to show how completely the drill proper for iron, follows the character of the turning tools for that metal; the flute or hollow filed behind the edge, gives the hook-formed acute edge required in this tool, which is in other respects like Fig. 528; the form proper for the cutting edge is shown more distinctly in the diagram *a*, Fig. 534.

Care should always be taken to have a proportional degree of strength in the shafts of the drills, otherwise they tremble and chatter when at work, or they occasionally twist off in the neck; the point should be also ground exactly central, so that both edges may be cut. As a guide for the proportional thickness of the point, it may measure at *b*, Fig. 531, the base of the cone, about one-fifth the diameter of the hole; and at *p*, the point, about one-eighth, for easier penetration: but the fluted drills are made nearly of the same thickness at the point and base.

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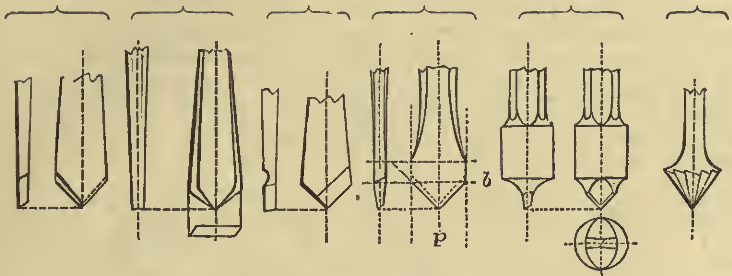

In all the drills previously described, except Fig. 526, the size of the point is lessened each time of sharpening; but to avoid this loss of size, a small part is often made parallel, as shown in Fig. 531 In Fig. 532, this mode is extended by making the drill with a cylindrical lump, so as to fill the hole; this is called the *recentering-drill.* It is used for commencing a small hole in a flat-bottomed cylindrical cavity; or else, in rotation with the common piercing-drill, and the half-round bit, in drilling small and very deep holes in the lathe. Fig. 532 may be also considered to resemble the *stop-drill*, upon which a solid lump or shoulder is formed, or a collar is temporarily attached by a side-screw, for limiting the depth to which the tool can penetrate the work.

Fig. 533, the *cone-countersink*, may be viewed as a multiplication of the common single-cutting drill Sometimes, however, the tool is filed with four equidistant radial furrows, directly upon the axis, and with several intermediate parallel furrows sweeping at an angle around the cone. This makes a more even distribution of the teeth than when all are radial as in the figure, and it is always used in the spherical cutters or countersinks known as *cherries*, which are used in making bullet-moulds.

On comparison, it may be said, the single-chamfered drill, Fig. 528, cuts more quickly than the double-chamfered, Fig. 522, but that the former is also more disposed of the two to swerve or *run* from its intended position. In using the double-cutting drills, it is also necessary to drill the holes at once to their full sizes, as otherwise the thin edges of these tools stick abruptly into the metal, and are liable

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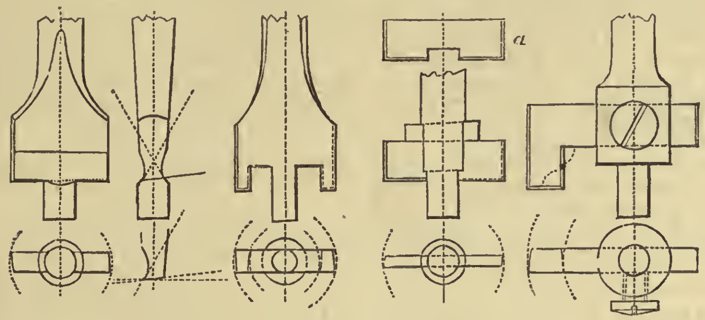


to produce jagged or groovy surfaces, which destroy the circularity of the holes; the necessity for drilling the entire hole at once, joined to the feebleness of the drill-bow, limits the size of these drills.

In using the single-chamfered drills it is customary, and on several accounts desirable, to make large holes by a series of two or more drills; first the run of the drill is in a measure proportioned to its diameter, therefore the small tool departs less from its intended path, and a central hole once obtained, it is followed, with little after-risk, by the single-cutting drill, which is less penetrative. This mode likewise throws out of action the less favorable part of the drill near the point, and which in large drills is necessarily thick and obtuse; the subdivision of the work enables a comparatively small power to be used for drilling large holes, and also presents the choice of the velocity best suited to each progressive diameter operated upon. But where sufficient power can be obtained, it is generally more judicious to enlarge the holes previously made with the pointed-drills, by some of the group of pin-drills, Figs. 534 to 537, in which the guide-principle is very perfectly employed: they present a close analogy to the plug centre-bit and the expanding centre-bit used in carpentry.

The ordinary *pin-drill*, Fig. 534, is employed for making countersinks for the heads of screw-bolts in laid flush with the surface, and also for enlarging holes commenced with pointed drills, by a cut parallel with the surface; the pin-drill is also particularly suited to thin materials, as the point of the ordinary

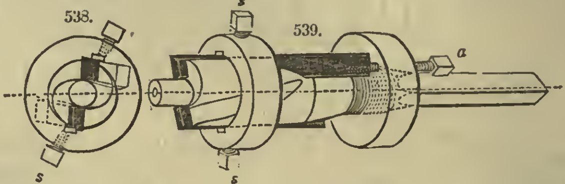
drill would soon pierce through, and leave the guidance less certain. When this tool is used for iron it is fluted as usual, and *a* represents the form of the one edge separately.

Fig. 535 is a pin-drill, principally used for cutting out large holes in cast-iron and other plates. In this case the narrow cutter removes a ring of metal, which is, of course, a less laborious process than cutting the hole into shavings. When this drill is applied from both sides it may be used for plates half an inch and upwards in thickness; as, should not the tool penetrate the whole of the way through, the piece may be broken out, and the rough edges cleaned with a file or a broach.

Fig. 536 is a tool commonly used for drilling the *tube-plates* for receiving the tubes of locomotive-boilers: the material is about $\frac{3}{4}$ inch thick, and the holes $1\frac{3}{4}$ diameter. The loose cutter *a* is fitted in a transverse mortise, and secured by a wedge; it admits of being several times ground before the notch which guides the blade for centrality is obliterated. Fig. 537 is somewhat similar to the last two, but is principally intended for sinking grooves; and when the tool is figured, as shown by the dotted line, it may be used for cutting bosses and mouldings on parts of work not otherwise accessible.

Many ingenious contrivances have been made to insure the dimensions and angles of tools being exactly retained. In this class may be placed Mr. Roberts' pin-drill, Figs. 538 and 539; in action it resembles the fluted pin-drill, Fig. 534, but the iron stock is much heavier, and is attached to the drilling-machine by the square tang; the stock has two grooves at an angle of about 10 degrees with the axis, and rather deeper behind than in front. Two steel cutters, or nearly parallel blades, represented black, are laid in the groves; they are fixed by the ring and two set-screws *s s*, and are advanced, as they become worn away, by two adjusting-screws *a a*, (only one seen,) placed at the angle of 10 degrees through the second ring; which, for the convenience of construction, is screwed upon the drill-shaft just beyond the square tang whereby it is attached to the drilling-machine. The cutters are ground at the extreme ends, but they also require an occasional touch on the oilstone to restore the keenness of the outer angles, which become somewhat rounded by the friction. The diminution from the trifling exterior sharpening, is allowed for by the slightly taper form of the blades.

538. 539.

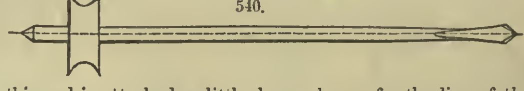


The process of drilling generally gives rise to more friction than that of turning, and the same methods of lubrication are used, but rather more commonly and plentifully; thus oil is used for the generality of metals—or from economy, soap and water; milk is the most proper for copper, gold, and silver; and cast-iron and brass are usually drilled without lubrication. For all the above-named metals, and for alloys of similar degrees of hardness, the common-pointed steel drills are generally used; but for lead and very soft alloys, the carpenters' spoon-bits and nose-bits are usually employed, with water. For hardened steel, and hard crystalline substances, copper or soft-iron drills, such as Figs. 529 or 530, supplied with emery-powder and oil, are needed; or the diamond drill-points, Figs. 531, 532, and 533, are used for hardened steel, with oil alone.

Having considered the most general forms of the cutting parts of drills, we will proceed to explain the modes in which they are put in action by hand-power, beginning with those for the smallest diameters, and proceeding gradually to the largest.

Methods of Working Drills by Hand-power.—The smallest holes are those required in watch-work, and the general form of the drill is shown on a large scale in Fig. 540; it is made of a piece of steel wire, which is tapered off at the one end, flattened with the hammer, and then filed up in the form shown at large in Fig. 522; lastly, it is hardened in the candle. The reverse end of the instrument is made into a conical point, and is also hardened; near this end is attached a little brass sheave for the line of the drill-bow, which, in watchmaking, is sometimes a fine horsehair, stretched by a piece of whalebone of about the size of a goose's quill stripped of its feather.

540.



The watchmaker holds most of his works in the fingers, both for fear of crushing them with the table-vice, and also that he may the more sensibly feel his operations; drilling is likewise performed by him in the same manner. Having passed the bowstring around the pulley in a single loop, (or with a *round turn*,) the centre of the drill is inserted in one of the small centre-holes in the sides of the table-vice, and the point of the drill is placed in the mark or cavity made in the work by the centre-punch; the object is then pressed forward with the right hand, whilst the bow is moved with the left.

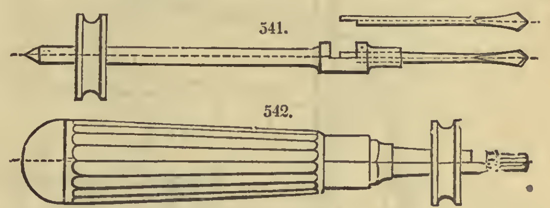
Clockmakers, and artisans in works of similar scale, fix the object in the tail-vice, and use drills, such as Fig. 540, but often larger and longer; they are pressed forward by the chest, which is defended from injury by the breastplate, namely, a piece of wood or metal about the size of the hand, in the middle of which is a plate of steel, with centre-holes for the drill. The breastplate is sometimes strapped round the waist, but is more usually supported with the left hand, the fingers of which are ready to catch the drill should it accidentally slip out of the centre.

As the drill gets larger the bow is proportionably increased in stiffness, and eventually becomes the half of a solid cone, about one inch in diameter at the larger end, and 30 inches long; the catgut string is sometimes nearly an eighth of an inch in diameter, or is replaced by a leather thong. The string is attached to the smaller end of the bow by a loop and notch, much the same as in the archery-bow, and is passed through a hole at the larger end, and made fast with a knot; the surplus length is wound round the cane, and the cord finally passes through a notch at the end, which prevents it from uncoiling.

Steel bows are also occasionally used; these are made something like a fencing-foil, but with a hook at the end for the knot or loop of the cord, and with a ferrule or a ratchet, around which the spare cord is wound. Some variations also are made in the sheaves of the large drills; sometimes they are cylindrical with a fillet at each end; this is desirable, as the cord necessarily lies on the sheave at an angle, in fact in the path of a screw; it pursues that path, and with the reciprocation of the drill-bow the cord traverses, or screws backwards and forwards upon the sheave, but is prevented from sliding off by the fillet. Occasionally, indeed, the cylindrical sheave is cut with a screw coarse enough to receive the cord, which may then make three or four coils for increased purchase, and have its natural screw-like run without any fretting whatever; but this is only desirable when the holes are large and the drill is almost constantly used, as it is tedious to wind on the cord for each individual hole. The structure of the bows, breastplates, and pulleys, although often varied, is sufficiently familiar to be understood without figures.

When the shaft of the drill is moderately long, the workman can readily observe if the drill is square with the work as regards the horizontal plane; and to remove the necessity for the observation of an assistant as to the vertical plane, a trifling weight is sometimes suspended from the drill-shaft by a metal ring or hook; the joggling motion shifts the weight to the lower extremity: the tool is only horizontal when the weight remains central.

In many cases, the necessity for repeating the shaft and pulley of the drill is avoided, by the employment of holders of various kinds, or *drill-stocks*, which serve to carry any required number of drill-points. The most simple of the drill-stocks is shown in Fig. 541; it has the centre and pulley of the ordinary drill, but the opposite end is pierced with a nearly cylindrical hole, just at the inner extremity of which a diametrical notch is filed. The drill is shown separately at *a*; its shank is made cylindrical, or exactly to fit the hole, and a short portion is nicked down also to the diametrical line, so as to slide into the gap in the drill-stock, by which the drill is prevented from revolving; the end serves also as an abutment whereby it may be thrust out with a lever. Sometimes a diametrical transverse mortise, narrower than the hole, is made through the drill-stock, and the drill is nicked in on both sides; the cylindrical hole of 541, should be continued to the bottom of the notch, the end of the drill should be filed off obliquely, and it should be prevented from rotating, by a pin inserted through the cylindrical hole parallel with the notch; the taper end of the drill would then wedge fast beneath the pin.



Drills are also frequently used in the *drilling-lathe;* this is a miniature lathe-head, the frame of which is fixed in the table-vice; the mandrel is pierced for the drills, and has a pulley for the bow, therein resembling Fig. 542, except that it is used as a fixture.

The Fig. 542 just referred to, represents one variety of another common form of the drill-stock, in which the revolving spindle is fitted in a handle, so that it may be held in any position, without the necessity for the breastplate; the handle is hollowed out to serve for containing the drills, and is fluted to assist the grasp.

Fig. 543 represents the socket of a "*universal drill-stock*," invented by Sir John Robinson; it is pierced with a hole as large as the largest of the wires of which the drills are formed, and the hole terminates in an acute hollow cone. The end of the drill-stock is tapped with two holes, placed on a diameter; the one screw, *a*, is of a very fine thread, and has at the end two shallow diametrical notches; the other, *b*, is of a coarser thread and quite flat at the extremity. The wire-drill is placed against the bottom of the hole, and allowed to lean against the adjusting-screw *a*, and if the drill be not central, this screw is moved one or several quarter-turns, until it is adjusted for centrality; after which the tool is strongly fixed by the plain set-screw *b*.

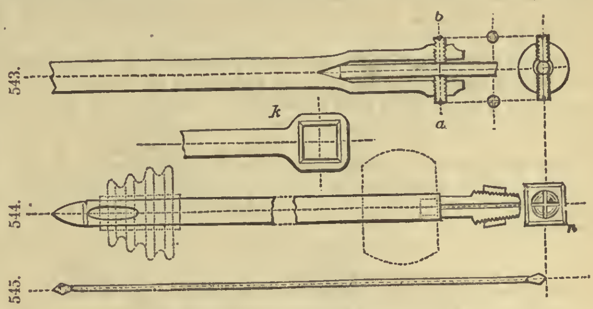


Fig. 544 is a drill-stock, contrived by Mr. William Allen: it consists of a tube, the one end of which has a fixed centre and pulley much the same as usual; the opposite end of the tube has a piece of steel fixed into it, which is first drilled with a central hole, and then turned as a conical screw, to which is fitted a corresponding screw-nut *n;* the socket is then sawn down with two diametrical notches, to make four internal angles, and lastly, the socket is hardened. When the four sections are compressed by the nut, their edges stick into the drill and retain it fast, and provided the instrument is itself concentric, and the four parts are of equal strength, the centrality of the drill is at once ensured. The outside of the nut, and the square hole in the key *k*, are each taper, for more ready application; and the drills are of the most simple kind, namely, lengths of wire pointed at each end, as in Fig. 545.

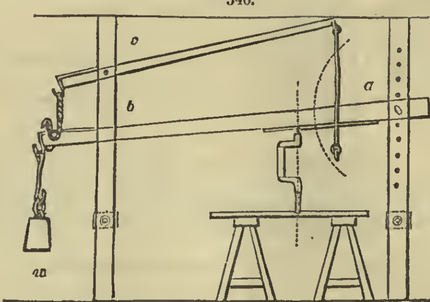
The sketch, Fig. 544, is also intended to explain another useful application of this drill-stock, as an *upright* or *pump drill*, a tool little employed in this country, (except in drilling the rivet-holes for mending china and glass, with diamond drill,) but as well known among the oriental nations as the breast-drill.

Holes that are too large to be drilled *solely* by the breast-drill and drill-bow, are frequently commenced with those useful instruments, and are then enlarged by means of the hand-brace, which is very similar to that used in carpentry, except that it is more commonly made of iron instead of wood, is somewhat larger, and generally made without the spring-catch.

Holes may be extended to about half an inch diameter, with the hand-brace; but it is much more expeditious to employ still larger and stronger braces, and to press them into the work in various ways by weights, levers, and screws, instead of by the muscular effort alone.

Fig. 546 represents the old smith's press-drill, which although cumbrous, and much less used than formerly, is nevertheless simple and effective. It consists of two pairs of wooden standards, between which works the beam *a b;* the pin near *a* is placed at any height, but the weight *w* is not usually changed, as the greater or less pressure for large and small drills, is obtained by placing the brace more or less near to the fulcrum *a;* and this part of the beam is shod with an iron plate, full of small centre-holes for the brace. The weight is raised by the second lever *c d*, the two being united by a chain, and a light chain or rope is also suspended from *d*, to be within reach of the one or two men engaged in moving the brace. It is necessary to relieve the weight when the drill is nearly through the hole, otherwise it might suddenly break through, and the drill becoming fixed, might be twisted off in the neck.

546.



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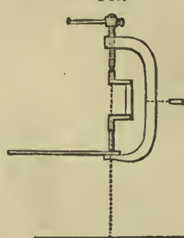


The inconveniences in this machine are, that the upper point of the brace moves in an arc instead of a right line; the limited path when strong pressures are used, which makes it necessary to shift the fulcrum *a;* and also the necessity for readjusting the work under the drill for each different hole, which in awkwardly-shaped pieces is often troublesome.

A portable contrivance of similar date, is an iron bow-frame or clamp, shown in Fig. 547; the pressure is applied by a screw, but in almost all cases, whilst the one individual drills the hole, the assistance of another is required to hold the frame; Fig. 547 only applies to comparatively thin parallel works, and does not present the necessary choice of position. Another tool of this kind, used for boring the side-holes in cast-iron pipes for water and gas, is doubtless familiarly known; the cramp or frame divides into two branches about two feet apart, and these terminate like hooks, which loosely embrace the pipe, so that the tool retains its position without constraint, and it may be used with great facility by one individual.

548.

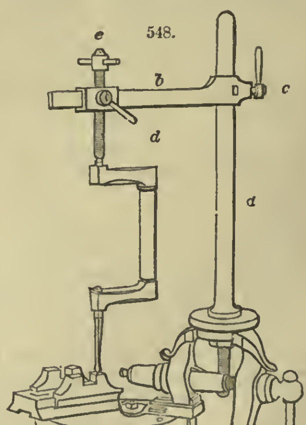


Fig. 548 will serve to show the general character of various constructions of more modern apparatus, to be used for supplying the pressure in drilling holes with hand-braces. It consists of a cylindrical bar *a*, upon which the horizontal rectangular rod *b* is fitted with a socket, so that it may be fixed at any height, or in any angular position, by the set-screw *c*. Upon *b* slides a socket, which is fixed at all distances from *a*, by its set-screw *d;* and lastly, this socket has a long vertical screw *e*, by which the brace is thrust into the work.

The object to be drilled having been placed level, either upon the ground, on trestles, on the work-bench, or in the vice, according to circumstances, the screws *c* and *d* are loosened, and the brace is put in position for work. The perpendicularity of the brace is then examined with a plumb-line, applied in two positions, (the eye being first directed as it were along the north and south line, and then along the east and west,) after which the whole is made fast by the screws *c* and *d*. The one hole having been drilled, the socket and screws present great facility in readjusting the instrument for subsequent holes, without the necessity for shifting the work, which would generally be attended with more trouble than altering the drill-frame by its screws.

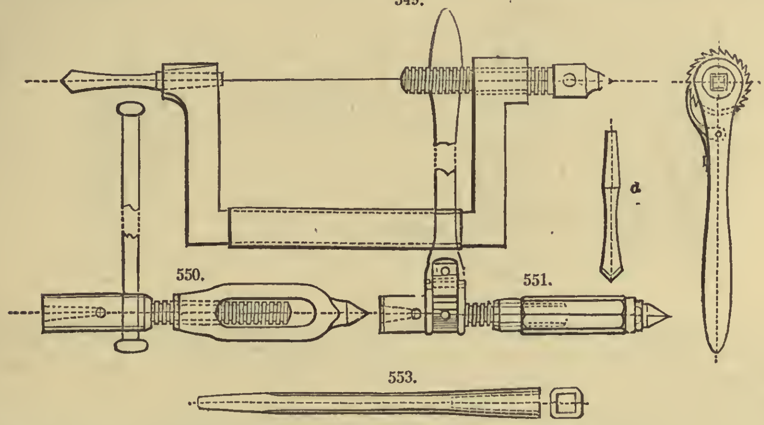
Sometimes the rod *a* is rectangular, and extends from the floor to the ceiling; it then traverses in fixed sockets, the lower of which has a set-screw for retaining any required position. In the tool represented, the rod *a* terminates in a cast-iron base, by which it may be grasped in the tail-vice, or when required it may be fixed upon the bench. In this case the nut on *a* is unscrewed; the cast-iron plate, when reversed and placed on the bench, serves as a pedestal; the stem is passed through a hole in the bench, and the nut and

washer, when screwed on the stem beneath, secure all very strongly together. Even in establishments where the most complete drilling machines driven by power are at hand, modifications of the press-drill are among the indispensable tools: many are contrived with screws and clamps, by which they are attached directly to such works as are sufficiently large and massive to serve as a foundation.

Various useful drilling tools for engineering works, are fitted with left-hand screws, the unwinding of which elongate the tools; so that for these instruments which supply their own pressure, it is only necessary to find a solid support for the centre. They apply very readily in drilling holes within boxes and panels, and the abutment is often similarly provided by projecting parts of the castings; or otherwise the fixed support is derived from the wall or ceiling, by aid of props arranged in the most convenient manner that presents itself.

Fig. 549 is the common brace, which only differs from that in Fig. 548 in the left-hand screw; a right-hand screw would be unwound in the act of drilling a hole when the brace is moved round in the usual direction, which agrees with the path of a left-hand screw. The cutting motion produces no change in the length of the instrument, and the screw being held at rest for a moment during the revolution, sets in the cut; but towards the last, the feed is discontinued, as the elasticity of the brace and work suffice for the reduced pressure required when the drill is nearly through, and sometimes the screw is unwound still more to reduce it.

549. 550. 551. 553.



The *lever-drill*, Fig. 550, differs from the latter figure in many respects; it is much stronger, and applicable to larger holes; the drill-socket is sufficiently long to be cut into the left-hand screw, and the piece serving as the screwed nut, is a loop terminating in the centre point. The increased length of the lever gives much greater purchase than in the crank-form brace, and in addition the lever-brace may be applied close against a surface where the crank-brace cannot be turned round; in this case the lever is only moved a half circle at a time, and is then slid through for a new purchase, or sometimes a spanner or wrench is applied directly upon the square drill-socket.

The same end is more conveniently fulfilled by the *ratchet-drill*, Fig. 551, apparently derived from the last; it is made by cutting ratchet-teeth in the drill-shaft, or putting on the ratchet as a separate piece, and fixing a pall or detent to the handle; the latter may then be moved backward to gather up the teeth, and forward to thrust round the tool, with less delay than the lever in Fig. 550, and with the same power, the two being of equal length. This tool is also peculiarly applicable to reaching into angles and places in which neither the crank-form brace nor the lever-drill will apply. Fig. 552, the *ratchet-lever*, in part resembles the ratchet-drill, but the pressure-screw of the latter instrument must be sought in some of the other contrivances referred to, as the ratchet-lever has simply a square aperture to fit on the tang of the drill *d*, which latter must be pressed forward by some independent means.

554. 555.

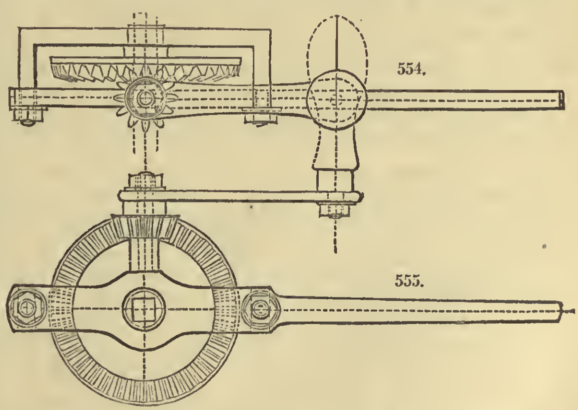


Fig. 553, which is a simple but necessary addition to the braces and drill tools, is a socket having at the one end a square hole to receive the drills, and at the opposite, a square tang to fit the brace; by this contrivance the length of the drill can be temporarily extended for reaching deeply-seated holes. The sockets are made of various lengths, and sometimes two or three are used together, to extend the length of the brace to suit the position of the prop; but it must be remembered, that with the additional length the tortion becomes much increased,

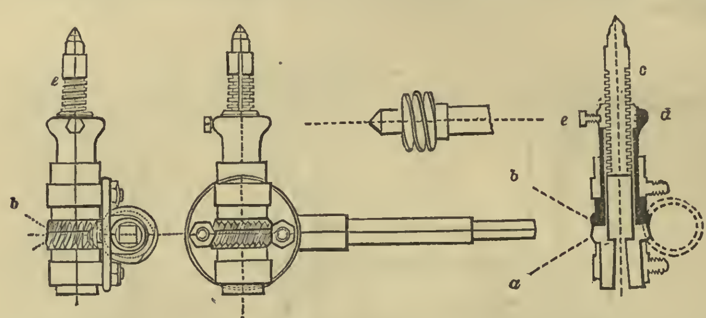
and the resistance to end-long pressure much diminished, therefore the sockets should have a bulk proportionate to their length.

The French brace, Fig. 521, is also constructed in iron, with a pair of equal bevel-pinions, and a left-hand centre-screw like the tools, Figs. 549, 550, and 551; it is then called the *corner-drill.* Sometimes, also, as in the succeeding Figs. 554 and 555, the bevel-wheels are made with a hollow square or axis, as in the ratchet-lever, Fig. 552; the driver then hangs loosely on the square shank of the drill-tool, or cutter-bar, and when the pinion on the handle is only one-third or fourth of the size of the bevel-wheel with the square hole, it is an effective driver for various uses; the long tail or lever serves to prevent the rotation of the driver, by resting against some part of the work or of the work-bench.

All the before-mentioned tools are commonly found in a variety of shapes in the hands of the engineer, but it will be observed they are all driven by hand-power, and are carried to the work. I shall conclude this section with the description of a more recent drill-tool of the same kind.

This instrument is represented of one-eighth size, in the side view, Fig. 556, in the front view, 557, and in the section, 558; it is about twice as powerful as Fig. 555, and has the advantage of feeding the

556. 557 558.



cut by a differential motion. The tangent-screw moves at the same time the two worm-wheels *a* and *b;* the former has fifteen teeth, and serves to revolve the drill; the latter has 16 teeth, and by the difference between the two, or the *odd tooth,* advances the drill slowly and continually, which may be thus explained.

The lower wheel *a*, of 15 teeth, is fixed on the drill-shaft, and this is tapped to receive the centre-screw *c*, of four threads per inch. The upper wheel of 16 teeth is at the end of a socket *d*, (which is represented black in the section Fig. 558,) and is connected with the centre-screw *c*, by a collar and internal key, which last fits a longitudinal groove cut up the side of the screw *c;* now therefore the internal and external screws travel constantly round, and nearly at the same rate, the *difference* of one tooth in the wheels serving continually and slowly to project the screw *c*, for feeding the cut. To shorten or lengthen the instrument rapidly, the side-screw *e* is loosened; this sets the collar and key free from the 16 wheel, and the centre-screw may for the time be moved independently by a spanner.

The *differential screw-drill,* having a double thread in the large worm, shown detached at *f*, requires 7½ turns of the handle to move the drill once round, and the feed is one 64th of an inch for each turn of the drill; that being the sum of 16 by 4.

Drilling and Boring Machines.—The motion of the lathe-mandrel is particularly proper for giving action to the various single-cutting drills referred to; they are then fixed in square or round hole drill-chucks which screw upon the lathe-mandrel. The motion of the lathe is more uniform than that of the hand-tools, and the popit-head, with its flat boring-flange and pressure-screw, form a most convenient arrangement, as the works are then carried to the drill exactly at right angles to the face. But in drilling very small holes in the lathe, there is some risk of unconsciously employing a greater pressure with the screw, than the slender drills will bear. Sometimes the cylinder is pressed forward by a horizontal lever fixed on a fulcrum; at other times the cylinder is pressed forward by a spring, by a rack and pinion motion, or by a simple lever, and the best arrangement of this latter kind is that next to be described.

In the manufacture of harps there is a vast quantity of small drilling, and the pressure of the cylinder popit-head is given by means of a long, straight, double-ended lever, which moves horizontally, (at about one-third from the back extremity,) upon a fixed post or fulcrum erected upon the backboard of the lathe. The front of the lever is connected with the sliding cylinder by a link or connecting-rod, and the back of the lever is pulled towards the right extremity of the lathe, by a cord which passes over a pulley at the edge of the backboard, and then supports a weight of about twenty pounds.

Both the weight and the connecting-rod may be attached at various distances from the fixed fulcrum between them. When they are fixed at equal distances from the axis of the lever, the weight, if twenty pounds, presses forward the drill with twenty pounds, less a little friction; if the weight be two inches from the fulcrum and the connecting-rod eight inches, the effect of the weight is reduced to five pounds; if, on the other hand, the weight be at eight and the connecting-rod at two inches, the pressure is fourfold, or eighty pounds.

The connecting-rod is full of holes, so that the lever may be adjusted exactly to reach the body of the workman, who, standing with his face to the mandrel, moves the lever with his back, and has therefore both hands at liberty for managing the work. Sometimes a stop is fixed on the cylinder, for drilling holes to one fixed depth; gages are attached to the flange for drilling numbers of similar pieces

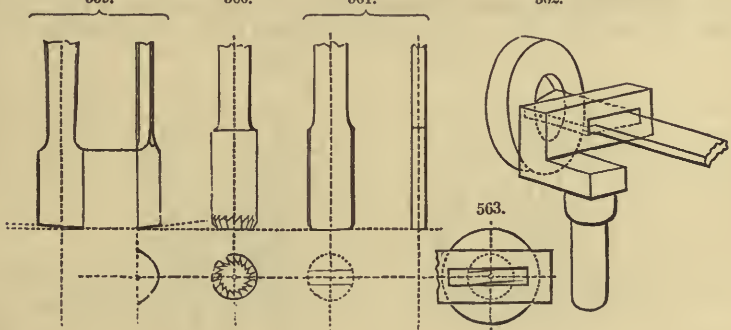
at any fixed distance from the edge: in fact, this very useful apparatus admits of many little additions to facilitate the use of drills and revolving cutters.

Great numbers of circular objects, such as wheels and pulleys, are chucked to revolve truly upon the lathe-mandrel, whilst a stationary drill is thrust forward against them, by which means the concentricity between the hole and the edge is ensured.

The drills employed for boring works chucked on the lathe, have mostly long shafts, some parts of which are rectangular or parallel, so that they may be prevented from revolving by a hook-wrench, a spanner, or a hand-vice, applied as a radius, or by other means. The ends of the drill-shafts are pierced with small centre-holes, in order that they may be thrust forward by the screw of the popit-head, either by hand or by self-acting motion; namely, a connection between either the mandrel or the prime mover of the lathe, and the screw of the popit-head, by cords and pulleys, by wheels and pinions, or other contrivances.

The drills, Figs. 528 and 530, are used for boring ordinary holes; but for those requiring greater accuracy, or a more exact repetition of the same diameter, the lathe-drills, Figs. 559 to 562, are commonly selected. Fig. 559, which is drawn in three views and to the same scale as the former examples, is called the *half-round bit*, or the *cylinder-bit*. The extremity is ground a little inclined to the right angle, both horizontally and vertically, to about the extent of three to five degrees. It is necessary to turn out a shallow recess exactly to the diameter of the end of the bit as a commencement, the circular part of the bit fills the hole, and is thereby retained central, whilst the left angle removes the shaving. This tool should never be sharpened on its diametrical face, or it would soon cease to deserve its appellation of *half-round* bit: some indeed give it about one-thirtieth more of the circumference. It is generally made very slightly smaller behind, to lessen the friction; and the angle, not intended to cut, is a little blunted half-way round the curve, that it may not scratch the hole from the pressure of the cutting edge. It is lubricated with oil for the metals generally, but is used dry for hard woods and ivory, and sometimes for brass.

559. 560. 561. 562.



563.

The rose-bit, Fig. 560, is also very much used for light finishing cuts, in brass, iron, and steel; the extremity is cylindrical, or in the smallest degree less behind, and the end is cut into teeth like a countersink; the rose-bit, when it has plenty of oil, and but very little to remove, will be found to act beautifully, but this tool is less fit for cast-iron than the bit next to be described. The rose-bit may be used without oil for the hard woods and ivory, in which it makes a very clean hole; but as the end of the tool is chamfered, it does not leave a flat-bottomed recess the same as the half-round bit, and is therefore only used for thoroughfare holes.

The drill, Fig. 561, is much employed, but especially for cast-iron work; the end of the blade is made very nearly parallel; the two front corners are ground slightly rounding, and are chamfered; the chamfer is continued at a reduced angle along the two sides, to the extent of about two diameters in length; this portion is not strictly parallel, but is very slightly largest in the middle, or barrel-shaped: this drill is used dry for cast-iron.

Fig. 561, in common with all drills that cut on the side, may, by improper direction, cut sidewise, making the hole above the intended diameter; but when the hole has been roughly bored with a common fluted drill, the end of the latter is used as a turning tool, to make an accurate chamfer; the bit 561 is then placed through the stay as shown in Fig. 562, and is lightly supported between the chamfer upon the work and the centre of the popit-head: the moment any pressure comes on the drill, its opposite edges stick into the inner sides of the loop, which thus restrains its position; much the same as the point and edges of the turning tools for iron dig into the rest, and secure the position of those tools.

It is requisite the drill and the loop should be exactly central. Fig. 562 shows the common form of the stay when fitted to the lathe-rest, but it is sometimes made as a swing-gate, to turn aside, whilst the piece which has been drilled is removed, and the next piece to be operated upon is fixed in the lathe. Sometimes also the drill 561, has blocks of hard wood attached above and below it, to complete the circle; this is usual for wrought-iron and steel, and oil is then employed.

These three varieties are exclusively lathe-drills, and are intended for the exact repetition of a number of holes of the particular sizes of the bits, and which, on that account, should remove only a thin shaving to save the tools from wear.

The cylinder bits, however, may be used for enlarging holes below half an inch, to the extent of about one-third their diameter at one cut; and for holes from half an inch to one inch, about one-fourth their

diameter or less; and as the bits increase in size, the proportion of the cut to the diameter should decrease.

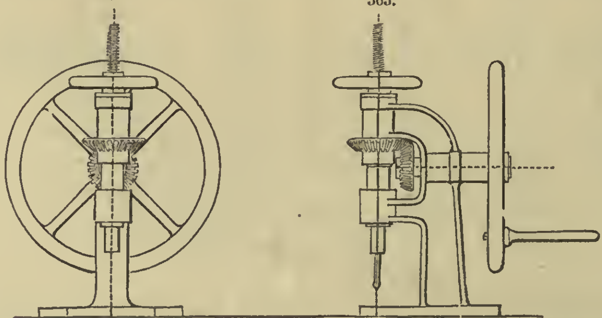
The cylinder bit is not intended to be used for drilling holes in the solid material, and as the piercing drills are apt to swerve in drilling small and very deep holes, the following rotation in the tools is sometimes resorted to. A drill, Fig. 531, say three-sixteenths diameter, is first sent in to the depth of an inch or upwards, and the hole is enlarged by a cylinder bit of one-quarter inch diameter. The centre at the end of the hole is then restored to exact truth, by Fig. 532, a recentering drill, the plug of which exactly fits the hole made by the cylinder bit; the extremity of the recentering drill then acts as a fixed turning-tool; and should the first drill have run out of its position, 532 corrects the centre at the end of the hole. Another short portion is then drilled with 528, enlarged with the half-round bit, and the conical extremity is again corrected with the recentering drill; the three tools are thus used in rotation until the hole is completed, and which may be then cleaned out with one continued cut, made with a half-round bit a little larger than that previously used.

Some of the large half-round bits are so made, that the one stock will serve for several cutters of different diameters. In the bit used for boring out ordnance, the parallel shaft of the boring-bar slides accurately in a groove, exactly parallel with the bore of the gun; the cutting blade is a small piece of steel affixed to the end of the half-round block, which is either entirely of iron, or partly of wood; and the cut is advanced by a rack and pinion movement, actuated either by the descent of a constant weight, or by a self-acting motion derived from the prime mover. For making the spherical, parabolical, or other termination to the bore, cutters of corresponding forms are fixed to the bar.*

There are very many works which, from their weight or size, cannot be drilled in the lathe in its ordinary position, as it is scarcely possible to support them steadily against the drill; but these works are readily pierced in the drilling-machine, which may be viewed as a lathe with a vertical mandrel, and with the flange of the popit-head enlarged into a table for the work, which then lies in the horizontal position simply by gravity, or is occasionally fixed on the table by screws and clamps. The structure of these important machines admits of almost endless diversity, and in nearly every manufactory some peculiarity of construction may be observed.

Figs. 564 and 565 exhibit Nasmyth's Portable Hand-drill, which is introduced as a simple and efficient example, that may serve to convey the general characters of the drilling-machines. The spindle

564. 565.



is driven by a pair of bevel-pinions; the one is attached to the axis of the vertical fly-wheel, the other to the drill-shaft, which is depressed by a screw moved by a small hand-wheel.

Sometimes, as in the lathe, the drilling-spindle revolves without endlong motion, and the table is raised by a treadle or by a hand-lever; but more generally the drill-shaft is cylindrical and revolves in, and also slides through, fixed cylindrical bearings. The drill-spindle is then depressed in a variety of ways; sometimes by a simple lever, at other times, by a treadle which either lowers the shaft only one single sweep, or by a ratchet that brings it down by several small successive steps, through a greater distance; and mostly a counterpoise weight restores the parts to their first position when the hand or foot is removed. Friction-clutches, trains of differential wheels, and other modes, are also used in depressing the drill-spindle, or in elevating the table by self-acting motion. Frequently also the platform admits of an adjustment independent of that of the spindle, for the sake of admitting larger pieces; the horizontal position of the platform is then retained by a slide, to which a rack and pinion movement, or an elevating screw, is added.

Drilling-machines of these kinds are generally used with the ordinary piercing-drills, and occasionally with pin-drills; the latter instrument appears to be the type of another class of boring tools, namely, *cutter-bars*, which are used for works requiring holes of greater dimensions, or of superior accuracy, than can be attained by the ordinary pointed drills.

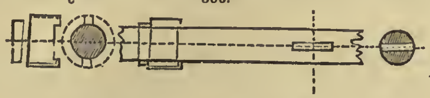
The small application of this principle, or of cutter-bars, is shown on the same scale as the former drills, in Fig. 566; the cutter *c*, is placed in a diametrical mortise in a cylindrical boring-bar, and is fixed by a wedge; the cutter *c* extends equally on both sides, as the two projections or ears embrace the sides of the bar, which is slightly flattened near the mortises.

Cutter-bars of the same kind, are occasionally employed with cutters of a variety of forms, for

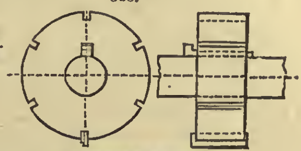
* The outside of the gun is usually turned, whilst the boring is going on, by the hand-tools. A plug of copper is screwed into the brass guns to be perforated for the touch-hole, copper being less injured by repeated discharges than the alloy of 9 parts copper and 1 part tin, used for the general substance of the gun; the curved bit smooths off the end of the plug.

making grooves, recesses, mouldings, and even screws, upon parts of heavy works, and those which cannot be conveniently fixed in the ordinary lathe. Fig. 567 represents one of these.

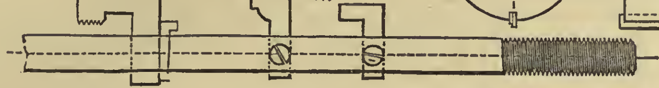
566.



568.



567.



The larger application of this principle is shown in Fig. 568, in which a cast-iron cutter-block is keyed fast upon a cylindrical bar; the block has four, six, or more grooves in its periphery. Sometimes the work is done with only one cutter, and should the bar vibrate, the remainder of the grooves are filled with pieces of hard wood, so as to complete the bearing at so many points of the circle; occasionally cutters are placed in all the grooves, and carefully adjusted to act in succession—that is, the first stands a little nearer to the axis than the second, and so on throughout, in order that each may do its share of the work; but the last of the series takes only a light finishing cut, that its keen edge may be the longer preserved. In all these cutters the one face is radial, the other differs only four or five degrees from the right angle, and the corners of the tools are slightly rounded.

These cutter-bars, like the rest of the drilling and boring machinery, are employed in a great variety of ways, but which resolve themselves into three principal modes:

First. The cutter-bar revolves without endlong motion, in fixed centres or bearings—in fact, as a spindle in the lathe; the work is traversed, or made to pass the revolving cutter in a right line, for which end the work is often fixed to a traversing slide-rest. This mode requires the bar to measure, between the supports, twice the length of the work to be bored, and the cutter to be in the middle of the bar; it is therefore unfit for long objects.

Secondly. The cutter-bar revolves, and also slides with endlong motion, the work being at rest; the bearings of the bar are then frequently attached in some temporary manner to the work to be bored, and are often of wood.*

In another common arrangement, the boring-bar is mounted in headstocks, much the same as a traversing mandrel, the work is fixed to the bearers carrying the headstocks, and the cutter-bar is advanced by a screw. The screw is then moved either by the hand of the workman, by a star-wheel, or a ratchet-wheel, one tooth only in each revolution, or else by a system of differential wheels, in which the external screw has a wheel, say of 50 teeth, the internal screw a wheel of 51 teeth, and a pair of equal wheels or pinions drives these two screws continually, so that the advance of the one-fiftieth of a turn of the screw, or their difference, is equally divided over each revolution of the cutter-bar, much the same as in the differential motion of the screw-drill, Fig. 556.

This second method only requires the interval between the fixed bearings of the cutter-bar to be as much longer than the work, as the length of the cutter-block; but the bar itself must have more than twice the length of the work, and requires to slide through the supports.

Cutter-bars of this kind are likewise used in the lathe; in the act of boring, the end of the bar then slides like a piston into the mandrel. Such bars are commonly applied to the vertical boring-machines of the larger kinds, which are usually fitted with a differential apparatus, for determining the progress of the cut; the bar then slides through a collar fixed in the bed of the machine.

In some of the large boring-machines either one or two horizontal slides are added, and by their aid, series of holes may be bored in any required arrangement. For instance, the several holes in the beams, or *side-levers*, and cranks of steam-engines are bored exactly perpendicular, in a line, and at any precise distances, by shifting the work beneath the revolving spindle upon the guide or railway; in pieces of other kinds, the work is moved laterally during the revolution of the cutters, for the formation of elongated countersinks and grooves.

Thirdly. In the largest applications of this principle, the boring-bar revolves upon fixed bearings without traversing; and it is only needful that the boring-bar should exceed the length of the work, by the thickness of the cutter-block, of which it has commonly several of different diameters. The cutter-block, now sometimes ten feet diameter, traverses as a slide down a huge boring-bar, whose diameter is about thirty inches. There is a groove and key to couple them together, and the traverse of the cutter-block down the bar is caused by a side-screw, upon the end of which is a large wheel, that engages in a small pinion, *fixed* to the stationary centre or pedestal of the machine. With every revolution of the cutter-bar, the great wheel is *carried around the fixed pinion*, and supposing these be as 10 to 1, the great wheel is moved one-tenth of a turn, and therefore moves the screw one-tenth of a turn also, and slowly traverses the cutter-block.

The contrivance may be viewed as a huge, self-acting, and revolving sliding-rest; the cutter-bars are equally applicable to portions of circles, such as the D-valves of steam-engines, as well as to the enormous interior of the cylinder itself.

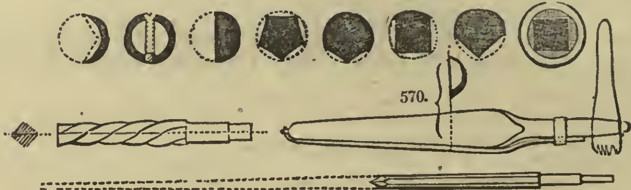
All the preceding boring tools cut almost exclusively upon the end alone.. They are passed entirely through the objects, and leave each part of their own particular diameter, and therefore cylindrical; but I now proceed to describe other boring tools, that cut only on their sides, go but partly through the

* Cylinders of 40 inches diameter for steam-engines have been thus bored by attaching a cast-iron cross to each end of the cylinder; the crosses are bored exactly to fit the boring-bar, one of them carries the driving-gear, and the bar is thrust endlong by means of a screw, moved by a ratchet or star wheel.

work, and leave its section a counterpart of the instrument. These tools are generally conical, and serve for the enlargement of holes to sizes intermediate between the gradations of the drills, and also for the formation of conical holes, as for valves, stopcocks, and other works. The common pointed drill, or its multiplication in the rose countersink, is the type of the series: but in general the broaches have sides which are much more nearly parallel.

Broaches for making taper holes.—The tools for making taper holes, are much less varied than the drills and boring tools for cylindrical holes. Thus the carpenter employs only the rimer, which is a fluted tool like the generality of his bits; it is sharpened from within, as shown in Fig. 569, so as to act like a paring tool. Flutes and clarionets are first perforated with the nose-bit, and then broached with taper holes, by means of tools of this kind, which are very carefully graduated as to their dimensions. Fig. 570 represents a German rimer, used by wheelwrights for inlaying the boxes of axletrees; the loose blade is separated from the shell of the instrument, by introducing slips of leather or wood between the two; the detached cutter fits on a pin at the front, and is fixed by a ring or collar against the shaft.

569. 571. 572. 573. 574. 575. 576. 577.



570.

578.

A curious rimer for the use of wine-coopers, by which the holes were made more truly circular, and the shavings were prevented from dropping into the cask. The stock of the instrument consists of a hollow brass cone, seen in section in Fig. 571; down one side there was a slit for containing a narrow blade or cutter, fixed by three or four screws placed diametrically. The tube was thus converted into a conical plane; the shavings entered within the tube, and were removed by taking out a cork from the small end of the cone.

The broaches for metal are made solid, and of various sections; as half-round, like Fig. 572; the edges are then rectangular. But more commonly the broaches are polygonal, as in Fig. 573, except that they have 3, 4, 5, 6, and 8 sides, and their edges measure respectively 60, 90, 108, 120, and 135 degrees. The four, five, and six-sided broaches are the most general, and the watchmakers employ a round broach in which no angle exists, and the tool is therefore only a burnisher, which compresses the metal and rounds the hole.

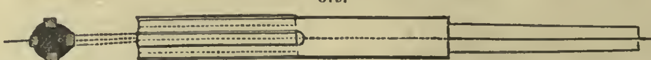
Ordinary broaches are very acute, and Fig. 574 may be considered to represent the general angle at which their sides meet—namely, less than one or two degrees; the end is usually chamfered off with as many facets as there are sides, to make a penetrating point, and the opposite extremity ends in a square *tang*, or shank, by which the instrument is worked.

Square broaches, after having been filed up, are sometimes twisted whilst red-hot. Fig. 577 shows one of these; the rectangular section is but little disturbed, although the faces become slightly concave. The advantage of the tool appears to exist in its screw form: when it is turned in the direction of the spiral, it cuts with avidity and requires but little pressure, as it is almost disposed to dig too forcibly into the metal: when turned the reverse way, as in unscrewing, it requires as much or more pressure than similar broaches not twisted. This instrument, if bent in the direction of its length, either in the act of twisting or hardening, does not admit of correction by grinding, like those broaches having plane faces. It is not much used, and is almost restricted to wrought-iron and steel.

Large countersinks that do not terminate in a point, are sometimes made as solid cones; a groove is then formed up one side, and deepest towards the base of the cone, for the insertion of a cutter, (see Fig. 574.) As the blade is narrowed by sharpening, it is set a little forward in the direction of its length, to cause its edge to continue slightly in advance of the general surface, like the iron of a plane for cutting metal.

Fig. 579 represents Mr. Richard Roberts' broach, in which four detached blades are introduced, for the sake of retaining the cone or angle of the broach with greater facility The bar or stock has four

579.



shallow longitudinal grooves, which are nearly radial on the cutting face, and slightly undercut on the other The grooves are also rather deeper behind, and the blades are a little wedge-form both in section and in length, to constitute the cone, and the cutting edges. In restoring the edges of the blades, they are removed from the stock, and their angles are then more easily tested: when replaced, they are set nearer to the point, to compensate for their loss of thickness.

Broaches are also used for perfecting cylindrical holes, as well as for making those which are taper The broaches are then made almost parallel, or a very little the highest in the middle; they are filed with two or three planes at angles of 90 degrees, as in Fig. 575 or 576. The circular part not being able to cut, serves as a more certain base for foundation, than when the tool is a complete polygon; and the stems are commonly made small enough to pass entirely through the holes, which then agree very exactly as to size. Such tools are therefore rather entitled to the name of finishing drills, than broaches

The size of the parallel broaches is often slightly increased, by placing a piece or two of paper at the convex part; leather and thin metal are also used for the same purpose. Gun-barrels are broached with square broaches, the cutting parts of which are about eight to ten inches long; they are packed on the four sides with slips or spills of wood, to complete the circle, as in Fig. 577, in which the tool is supposed to be at work. The size of the bit is progressively enlarged by introducing slips of thin paper, piece by piece between two of the spills of wood and the broach; the paper throws the one angle more towards the centre of the hole, and causes a corresponding advance in the opposite or the cutting angle. Sometimes, however, only one spill of wood is employed.

A broach used by the philosophical instrument makers in finishing the barrels of air-pumps, consisted of a thin plate of steel inserted diametrically between two blocks of wood, the whole constituting a cylinder with a scraping edge slightly in advance of the wood; slips of paper were also added.

According to the size of the broaches, they are fixed in handles like brad-awls; they are used in the brace, or the tap-wrench—namely, a double-ended lever with square central holes. Sometimes also broaches are used in the lathe just like drills, and for large works, broaching machines are employed; these are little more than driving-gear terminating in a simple kind of universal joint, to lead the power of the steam-engine to the tool, which is generally left under the guidance of its own edges, according to the common principle of the instrument.

In drills and broaches, the penetrating angles are commonly more obtuse than in turning tools; thus in drills of limited dimensions, the hook-form of the turning tool for iron is inapplicable, and in the larger examples, the permanence of the tool is of more consequence than the increased friction. But on account of the additional friction excited by the nearly rectangular edges, it is commonly necessary to employ a smaller velocity in boring than in turning corresponding diameters, in order to avoid softening the tool by the heat generated; and in the ductile fibrous metals, as wrought-iron, steel, copper, and others, lubrication with oil, water, &c., becomes more necessary than in turning.

The drills and broaches form together a complete series. First the cylinder-bit, the pin-drills, and others with blunt sides, produce cylindrical holes by means of cutters at *right angles* to the axis; then the cutter becomes *inclined* at about 45 degrees, as in the common piercing-drill and cone countersink; the angle becomes much less in the common taper broaches; and finally disappears in the parallel broaches, by which we again produce the cylindrical hole, but with cutters *parallel* with the axis of the hole.

Still considering the drills and broaches as one group, the drills have comparatively thin edges, always less than 90 degrees, yet they require to be urged forward by a screw or otherwise, the resistance being sustained in the line of their axes. The broaches have much more obtuse edges, never less than 90, and sometimes extending to 135 degrees; and yet the greater force required to cause the penetration of their obtuse edges into the material, is supplied without any screw, because the pressure in all these varied tools is at right angles to the cutting edge.

Thus supposing the sides of the broach extended until they meet in a point, as in Fig. 578, we shall find the length will very many times exceed the diameter, and by that number will the force employed to thrust forward the tool be multiplied, the same as in the wedge, whether employed in splitting timber or otherwise; and the broach being confined in a hole, it cannot make its escape, but acts with great lateral pressure, directed radially from each cutting edge; and the broach under proper management leaves the holes very smooth and of true figure.

BOX-WOOD. See Woods, *varieties of.*

BRACE. See Boring Tools.

BRACKETS AND PILLOW-BLOCKS. See Geering.

BRAKE. The drag applied generally to the wheels of carriages to check their velocity in passing down hills, by means of friction. The brake attached to railway carriages consists of a piece of wood, which is pressed upon the rim of the wheels of the carriages by a hand-lever, worked by the brakeman. The brake of the tender alone affords a sufficient resistance to stop a train under ordinary circumstances. The term is also used in reference to the contrivance for arresting the motion of machinery.

On English railways brakes are applied to the wheels of a part only of the carriages attached to a train; these are termed guard vans. The number of these brake carriages depending upon the inclinations of the line and the speeds employed. The engine also is generally reversed to assist the brakes. It must be recollected, however, that by stopping a train too rapidly, great injury results both to the permanent way and the rolling stock.

The following considerations should determine the amount of brake power required.

The forces which act on the train after the steam has been shut off, are the axle friction and rolling friction of the train, and the pressure of the wind; the friction tends gradually to bring the train to rest, the pressure of the wind to accelerate or retard it, as the case may be, and this will therefore be omitted from the conclusions to be drawn.

To stop a train rapidly, brakes are applied to some of the wheels, and the engine is reversed. The application of brakes prevents the wheels from revolving, and introduces the friction due to the weights on the wheels to which brakes are applied. The act of reversing the engine does not immediately stop the forward motion of the driving wheel, but forces it to revolve at a somewhat slower rate than that due to the speed of the train, and thus causes a friction of surfaces to take place between the wheel and rail.

The axle and rolling friction may be assumed to be some proportion of the total weight of the train; the friction of the wheels to which brakes are applied may be taken as some proportion of the insistent weights: by experiment on English railways, it appears that the axle and rolling friction may be taken at $\frac{1}{334}$ part of the weight of the train, and the friction due to the brakes at about $\frac{1}{5}$ of the weight on them.

Hence, if l represent the gross load of the train,
w " the weight on the wheels to which brakes are applied,
R " the retardation in feet per second,
g " the force of gravity,
and, if the train be on an incline,
$\frac{1}{p}$ represent the slope of such incline,

$$R = \left\{ \frac{l-w}{334} + \frac{w}{8} \pm \frac{2}{p} \right\} \frac{g}{l},$$

the latter term being used with the negative sign when the train is descending, and the positive sign when ascending the gradient.

If $S =$ space traversed by the train in coming to rest,
$v =$ velocity in feet per second at the moment the steam is shut off and the brakes applied,

$$S = \frac{v^2}{2 R}$$

In estimating practically the space which would be required for a train to stop in, eight or ten seconds should be allowed for time lost in applying the brakes.

Since more than half the total number of fatal accidents which occur upon railroads arise from collision, it is important that the attention of railroad companies should be specially directed to precautions against this source of danger. The possibility of preventing collision will depend upon the proportion which the number of brakes and brakemen upon the train bears to its weight and speed. It is found by experience that the distance within which a train of given weight can be brought to rest by a given number of brakes, will be in proportion to the square of its speed, that is to say, with a double speed it will require four times the number of brakes; with a treble speed nine times the number of brakes, and so on.

The means of stopping a train are, the brake on the tender, the brakes on the cars, *and in fine, reversing the action of the engine.* This is a dangerous process. In this way the whole force of the steam is suddenly made to resist the progressive motion of the engine; the cars are consequently urged against the engine, and against each other, and the obvious tendency is to throw the cars from the rails by *doubling up the train.* Before reversing the engine, or even applying the brake to the tender, it is therefore advisable to warn the brakemen to apply the brakes to the cars composing the train; this being done, and the brake being then applied to the tender, there is less danger in reversing the steam on the engine, the whole train remaining elongated by the friction of the brakes applied to the rear cars.

The common form of car brake at present in use, is operated by a brakeman standing on the platform at either end of the car. A vertical rod turning in a step at the bottom is made to wind up by means of a hand wheel, a few links of chain connecting by an iron rod with a lever attached to the bottom of the car. This lever acts directly on a heavy wooden bar suspended from the car trucks by hooks and chains at either end. The ends of these bars support the friction blocks, which are of wood lined with metal, and are made to bear directly upon the periphery of the wheel. By means of a small ratchet wheel and detent on the platform, the vertical rod is held stationary when the brakes are put on, and is released when the motion of the train is stopped; the action of this form of brake is direct, simple and efficient.

Various forms of self-acting brakes have been devised, and much ingenuity has been displayed in the endeavour to obtain this object, and although none of them are as yet in general use, the importance of security from accident in railway travel, demands a careful investigation of the best methods of preventing collisions by this means.

In "Loughridge's Self-acting Car Brake," the cars are stopped by the friction of the ordinary brakes, but the power actuating them is derived directly from a drum shaft on the locomotive. This shaft, or rather pulley keyed thereon, is pressed into contact with the flange of the driving wheels, and is thus compelled to revolve and wind up a stout chain running the length of the train beneath the cars. This chain applies the brakes of all the cars. To prevent pulling too severely and fracturing some portion of the mechanism, provision is made for limiting the extent of its action by causing it to release its hold of the driving wheel so soon as a certain portion of the chain is taken up. The point at which this unshipping movement comes into play is previously arranged by the engineer, so that however excited in view of danger, or careless and bungling, he cannot endanger the integrity of any important part.

To cause one continuous chain to operate all the brakes, an ingenious arrangement is adopted. A stout lever, some three or four feet long, is hung under each car, and provided with sheaves or pulleys at each end, around which the chain makes a curve like the letter S, and continues on to the next. When the chain is pulled by the winding of the shaft, this lever is moved by the tension, and forces the brakes into contact with the wheels.

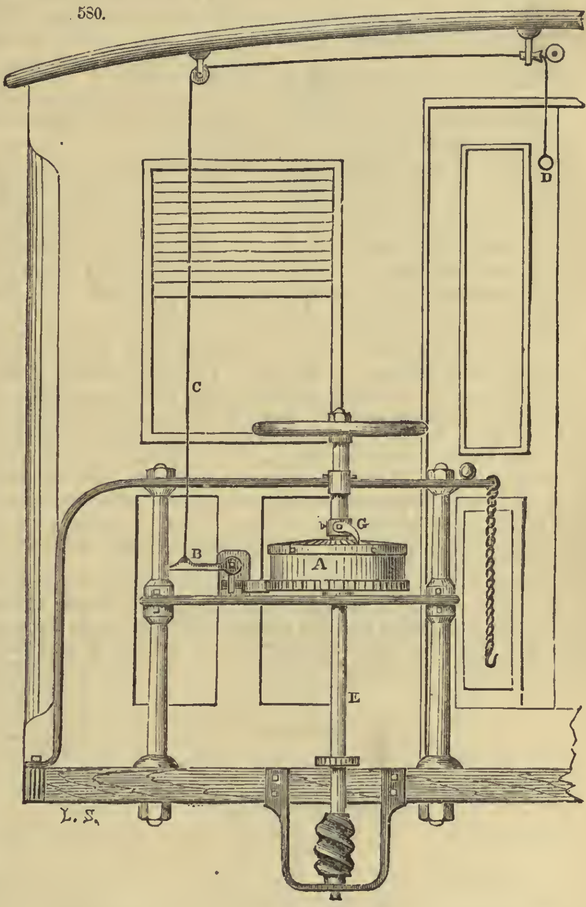
The United States Railroad Car Brake of Wm. G. Creamer, is an improved method of operating brakes, by bell or signal cords, as represented in fig. 580.

The principal features of this invention and its operation, are as follows:—To the ordinary hand wheel and brake-shaft, (for winding up the brakes,) is attached a drum A or loose pulley containing a strong spiral spring. This spring is wound up by a reverse motion of the brake-shaft, to which is attached an arm and pawl G, taking into a circle of ratchet teeth on the top of the drum A. When the spring is wound ready for use, it is held in check by a lever B, from the extremity of which passes a branch line to the top of the car at D, and connecting about three feet forward to the bell-cord. The branch line is attached to the lever B by a ring in such a way that when the lever is drawn up vertically the ring disconnects. This is rendered necessary to insure the working of the brakes by the bell-cord whether the train is extended on an up grade, or contracted on a down grade. The attachment

of the branch line of each car, some three feet forward, enables the engineer to apply the brakes of all the cars simultaneously, by pulling the bell-cord, and at the same time it does not interfere with the bell-cord as a means of enabling the conductor to signalise the engineer. When the conductor pulls the bell-cord it rings the bell, and simply makes slack on the several branch lines connected with the brake, but does not operate the brake. The conductor, brakeman, or even passengers however can, if an emergency arises in any part of the train, instantly close all the brakes, by pulling the bell-cord, or any accidental separation of the train produces the same effect, namely, bringing the retarding force on all the cars into instant action.

A train has been repeatedly stopped with this apparatus within 350 feet at 30 miles per hour; the brakes being shod with cast iron; with wooden shoes, a train may be stopped within 250 feet.

580.



The advantages claimed for this invention are as follows:

First.—It enables the Engineman in any sudden emergency or premonition of danger, instantly to apply the brakes of every car of the train, (without signals or brakemen,) with their utmost power, and hold each car by itself, independent of each other, even if the engine or a part of the cars are thrown from the track.

Second.—It also enables the conductor, brakeman, or even passengers of the train, whether moving forward or backward, in front or rear, in any emergency, to apply every brake of the entire train in an instant, without reference to its length.

Third.—It involves no alteration in the construction or method of working the present brakes, puts no additional machinery or apparatus under the cars, exposed to dust and friction, and where it cannot be seen when the train is in motion, but places the entire mechanism on the platform, where it is constantly under the eye of the brakeman and attendants of the train.

Fourth.—Each car having an independent arrangement of its own, a train can be made up with a part of the cars fitted with this apparatus and a part without. Those fitted with the apparatus can be connected with the bell-cord, and when required, the brakes can be worked as previously described. This will be a great advantage where passenger cars are behind freight or cattle trains.

Fifth.—No additional machinery or mechanism is required on the engine. No additional responsibility is put upon the engineer. In case of danger, instead of giving the usual signals, he would give the bell-cord a jerk, (which would apply every brake instantly,) and reverse his engine. He could then jump off if he chose.

Sixth.—This improvement does not interfere with the use of the signal-cord for transmitting signals to the engineer, nor does it interfere with the use of the brakes by hand, even when set, and ready for use by the bell-cord. While the brake is being applied by hand, the engineer can release the latch and finish the work in an instant. The connection of the brake operator with the hand-wheel can be maintained constantly without interrupting the operation of either plan.

Seventh.—This apparatus being connected to, and identified with the common brake-shaft under the hand-wheel, its position is such, that it is constantly seen by the brakeman or attendants of the train; and if out of order, the fact is immediately known, and the remedy applied. This would not be the case if it were placed on the top, or under the car, or anywhere out of constant sight.

Eighth.—Two brakemen are all that is really necessary in a train of any length, or (not exceeding eight cars) so far as the ordinary stoppages are concerned, while at the same time, the means are at hand for the instant and powerful application of every brake from any part of the train if required. In any such case it would be necessary for the brakeman to go to each car and release the brakes. Such emergencies would not of course be of daily occurrence, and the time required would not exceed

a minute, which is a matter of no consequence whatever. If brakemen are placed for every two cars, as ordinarily, the whole brakes could be released in a moment as now on signal.

The damage from breaking of a chain, or rail, or wheel, or axle, will be greatly mitigated on trains where this invention is used. In the first place, in sudden danger the engineer does not give the signals, or if given at all, they are given hurriedly, and perhaps not heard or understood, or if heard at unexpected places, the brakeman, if on the platform, cannot avoid the temptation to look out and see what is the matter; if there is an impending crash in view, he cannot resist the inclination to jump off, or at least to get inside the car; no man under the circumstances can deliberately exert his whole strength on the platform; the consequence is, that little or nothing can be done towards averting an accident by the present brakes as applied by hand. Trains never can, or never will, be run without brakemen or attendants; at least two men are wanted besides the conductor, for baggage and brakes on trains of four or five cars. They are called brakemen, but the application of the brakes, for all ordinary purposes, is a very small portion of their duties. They have to clean the cars, trim the lamps, examine the boxes, make the fires, wood up at stations, take back signals, &c., &c. Just as many men would be wanted, supposing they would not be wanted as brakemen.

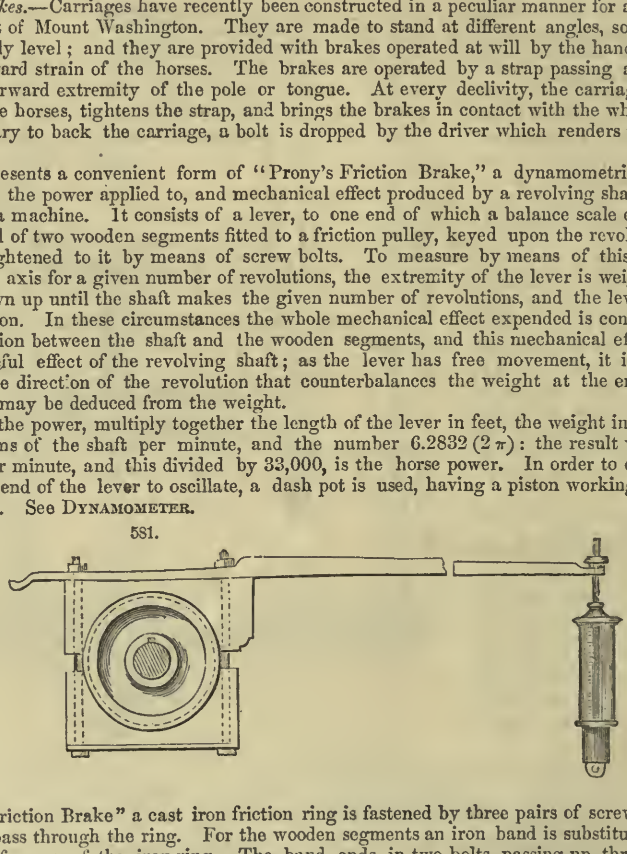
This apparatus may be described as a *mechanical connection of all the brakes of the train in one controlling power, and that furnishes the means of direct and instant application, perfectly accessible from the engine or any part of the train.*

Carriage Brakes.—Carriages have recently been constructed in a peculiar manner for a turnpike road over the summit of Mount Washington. They are made to stand at different angles, so that the floors are always nearly level; and they are provided with brakes operated at will by the hand of the driver, or by the backward strain of the horses. The brakes are operated by a strap passing around a pulley or ring in the forward extremity of the pole or tongue. At every declivity, the carriage in crowding forward upon the horses, tightens the strap, and brings the brakes in contact with the wheels. When it becomes necessary to back the carriage, a bolt is dropped by the driver which renders the brakes inoperative.

Fig. 581, represents a convenient form of "Prony's Friction Brake," a dynamometrical instrument used to measure the power applied to, and mechanical effect produced by a revolving shaft, or other revolving part of a machine. It consists of a lever, to one end of which a balance scale or weights may be attached, and of two wooden segments fitted to a friction pulley, keyed upon the revolving shaft, and which can be tightened to it by means of screw bolts. To measure by means of this arrangement, the power of the axis for a given number of revolutions, the extremity of the lever is weighted, and the screw bolts drawn up until the shaft makes the given number of revolutions, and the lever maintains a horizontal position. In these circumstances the whole mechanical effect expended is consumed in overcoming the friction between the shaft and the wooden segments, and this mechanical effect is *equal* to the work or useful effect of the revolving shaft; as the lever has free movement, it is only the friction acting in the direction of the revolution that counterbalances the weight at the end of the lever, and the friction may be deduced from the weight.

To calculate the power, multiply together the length of the lever in feet, the weight in lbs., the number of revolutions of the shaft per minute, and the number 6.2832 (2π): the result will be the lbs. raised 1 foot per minute, and this divided by 33,000, is the horse power. In order to counteract the tendency of the end of the lever to oscillate, a dash pot is used, having a piston working in a cylinder filled with water. See DYNAMOMETER.

581.



In "Eger's Friction Brake" a cast iron friction ring is fastened by three pairs of screws on any sized shaft that will pass through the ring. For the wooden segments an iron band is substituted, embracing half the circumference of the iron ring. The band ends in two bolts passing up through a wooden beam, and may be tightened at will by means of screw nuts. To prevent the firing of the wood, or excessive heating of the iron, water is constantly supplied through a small hole in the beam.

Example. To determine the mechanical effect produced by a water wheel, a friction brake was placed in the shaft, and when the water let on had been perfectly regulated for six revolutions per minute, the weight G, including the reduced weight of the instrument, was 530 lbs.; the leverage of this weight was $a = 10.5$ feet. From these quantities the effect given off by the water wheel is deduced.

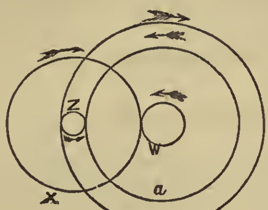
$$L = \frac{\pi.\ 6.\ 10.5.}{30}\ 530 = 3497 \text{ feet. lbs.} = 6.3 \text{ horse power.}$$

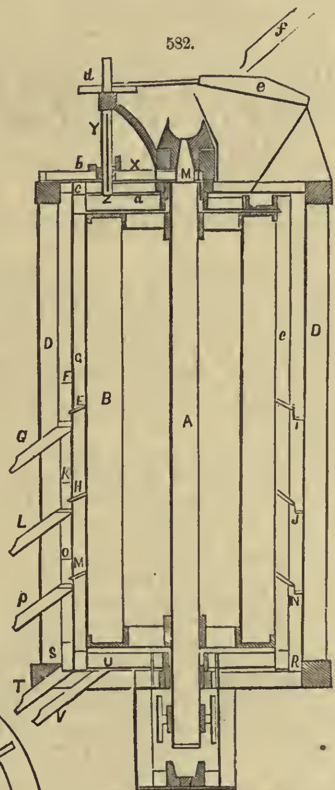
BRAN SEPARATOR. This is the invention of E. R. Benton, of Milwaukie, Wisconsin, and it has been deemed one of no minor importance. The following description of its construction and operation in connection with the accompanying engravings, will enable our readers fully to understand it.

Fig. 581 is a sectional view, and Fig. 583 a sectional plan, with the top parts removed in order more plainly to show the parts represented in Fig. 582. A, is the shaft. B, the cylinder. C, the inner re-

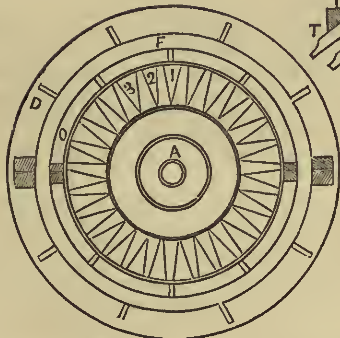
volving shell; and D, the outer or stationary shell. The cylinder is made by framing staves of the form, and in the position represented at 1, 2, 3, &c., Fig. 583, into corresponding cast heads. The staves thus forming the longitudinal and working surface, and which may be covered with any kind of material that will make it rough and durable. Air is let into the cylinder, the best at the lower end, through equidistant holes around the centre, and the quantity gaged by a circular revolving slide, and spaces between the staves emit it to carry the flour and other stuffs through the several qualities of wire-cloth with which the inner surface of the revolving shell is covered. The cylinder is driven by a belt and

582.





583.



pulleys, as is represented at the bottom of Fig. 582; and the bridge and oilpot for the point and step, and the fixture for supporting the upper journal-box of the shaft, are cast in a piece with their respective heads of the outer shell, thus rendering this part of the machine perfect. The inner surface of the revolving shell is covered with the above-named wire-cloth. Thus, the space between the top and the bevelled dividing ring E, Fig. 582, is covered with a quality that will let through little else but pure flour, which falls, and by the dividing ring is conducted into an endless trough I, attached to the inner and sheet-iron or zinc-lined surface of the stationary shell, and by the sweepers F, attached to the revolving shell, is brought around and discharged at the spout G. The space between the dividing rings E and H is covered with a quality that will discharge an inferior quality to the above, which falls, as above into the endless trough J, and by the sweepers K, is brought around and discharged at the spout L. The space between the dividing rings H and M is covered with a quality that will take out the fine particles of the bran, called dusting, which falls, as above, into the endless trough N, and by the sweepers O, is discharged at the spout P. The space between the dividing ring M and the bottom, is covered with a quality that will separate the shorts from the bran, the shorts falling to the bottom, or into the endless trough R, and by the sweepers S is discharged at the spout T, the bran passing down inside of the revolving shell, and by the arms U, of its cast head, is swept around to, and discharged

at the spout V. The revolving shell is driven by a combination of gear-wheels, thus: The pinion above, on the principal shaft A, Fig. 582, drives the wheel X, on the small or centre shaft Y, and the pinion Z, on the last-named shaft, drives the projecting cogged-wheel rim *a*, cast in a piece with the top head, which will turn it the same way with the cylinder; and to turn it the contrary way, the projecting rim *a* must be so large as to circumscribe and be driven by the pinion Z, working into cogs upon its inner periphery, as seen by the figures W, of pitch circles, the figures denoting the corresponding pitch circles of the wheels and pinions in Fig. 582. *b*, is a circular inclined plane, so calculated as to lift a mallet or hammer to strike upon the end of the revolving shell to keep the cloth from clogging, the blow to be struck upon a block resting upon its upper rim, and projecting up through a corresponding hole in the stationary head, as at C. *d*, is a set of cams on the shaft Y, which shake a wire sieve *e*, that receives the uncleaned and unseparated bran, shorts, and dustings from the bolts, as through the spout *f*, the sieve carrying off all coarse extraneous stuff that might injure the machine, the bran falling through the sieve and entering the machine passing between the arms of the upper head of the revolving shell on to the head of the cylinder.

BRASS. See METALS AND ALLOYS.

BRASSES. A term applied by mechanics to boxes or bushings of brass.

BRAZILETTO. See WOODS, *varieties of.*

BRAZIL-WOOD. See WOODS, *varieties of.*

BRAZING, the soldering together of edges of iron, copper, brass, &c., with an alloy of brass and zinc, called spelter solder.

BREAD. The only substance adapted to the making of good fermented bread is the flour of wheat. The essential constituents of wheat flour are starch, also called farina or fecula, gluten, and a little albumen. According to Vogel, 100 parts of wheat flour contain, of starch 68 parts, gluten 24, gummy sugar 5, and albumen 1-5; but these proportions vary with the goodness of the wheat.

The starch of wheat flour is very nutritive. Gluten is a mixture of vegetable fibrine, and a small quantity of a peculiar matter containing nitrogen, called *gliadine*, to which its adhesive properties are due. The small proportion of sugar in wheat flour enables it to ferment on being mixed with water, without the addition of yeast. Thus the dough of wheat flour, by spontaneous fermentation, becomes converted into leaven.

During the rising of the dough, carbonic acid is formed at every part, and is prevented from escaping by the gluten, which forms a kind of adhesive web. The formation of this gas causes the dough to swell in every direction, and the particles of starch to separate, in which condition the process is arrested by the heat of the oven, so that when the bread is cut open, it is piled full of cavities, each of which in the dough contained a globule of carbonic acid.

In the preparation of wheat for the manufacture of bread, the ground grain is usually separated into three parts, the *flour*, the *pollard*, and the *bran;* the flour forms, on an average, about three-fourths of the wheat ground. The white flour is pleasing both to the eye and taste, and there is a strong prejudice in favor of white bread; hence various methods of bleaching are resorted to, but it is doubtful if the whitest bread, even supposing it to be pure, is conducive to health and economy. By rejecting the *bran*, as we do when using only the finest flour for bread, we actually lose a large amount of nourishment of the most important kind. According to Liebig, the separation of bran from the flour *is rather injurious than useful to nutrition.* By using unbolted flour for bread the product is increased at least one fifth. From the several varieties of flour obtained by *bolting*, three kinds or classes of bread are manufactured. 1. Wheaten bread, or *firsts*, which is made of the finest flour; 2. household bread, or *seconds*, which is somewhat coarser; 3. brown bread, *thirds*, which is made of flour of various degrees of coarseness. For making firsts, the flour is entirely separated from the bran or husks; in the other descriptions the bran is not entirely removed, but the coarse broad bran is separated from the coarsest flour.

The baker generally takes a portion only of the water which he intends to employ in making the required quantity of dough, at a temperature of from 70° to 100°, and containing a portion of salt necessary to give the bread its proper flavor. Yeast is next mixed with the water, and then a portion of flour is added, always less than the quantity intended for the finished dough. The mixture is covered up and left in a warm situation. In about an hour this mixture, termed the *sponge*, thus set apart, begins to ferment. It swells out and heaves up, evidently in consequence of the generation of some internal elastic fluid, which, in this instance, is carbonic acid gas. When no longer capable of retaining the pent-up air, it bursts and subsides. After the second or third rising and dropping of the sponge, the baker interferes, otherwise the bread formed from this dough would be sour. At this period he therefore adds to the sponge the remaining portions of flour and water and salt, necessary to form the dough into the required consistence and size, and next incorporates all these materials with the sponge, by long and laborious kneading. The dough is left to itself for a few hours, during which time it continues in an active state of fermentation throughout its whole extent. After a second kneading, to distribute the gas within it as equally as possible throughout the whole mass, the dough is weighed out into portions requisite to form the kinds of bread desired. These loaves are once more set aside for an hour or two in a warm place, and the continued fermentation soon expands each mass to about double its former volume. They are now considered fit for the fire, and are finally baked into loaves, which when they quit the oven, are nearly twice as large as when they entered it. The gas contained in the bread is expanded by the heat throughout every part of the loaf, and swells out its whole volume, giving it the piled vesicular structure. Thus a well-made and well-baked loaf is composed of an infinite number of cellules, each of which is filled with carbonic acid gas, and lined with, or composed of, a glutinous membrane; and it is this that communicates the light, elastic, porous texture to bread.

Various arrangements are in use for making bread by machinery. The usually laborious occupation of kneading and mixing the dough is now perfectly well performed by mechanical means, and automatic

ovens receive the dough and return it baked to the basket. Thus large quantities of perfect bread are made expeditiously and at a low price.

The following is a description of Berdan's Automatic Oven, in Brooklyn, N. Y.:

"The oven is of brick, eighteen feet long, nine feet broad, and thirty-two feet high, having a lower and upper story. Underneath the oven is a furnace, from which the heat is conducted to, and through the oven, by means of fire-brick tubes; and the furnace is so constructed and arranged that, by means of a self-acting damper attached to a piece of metal, which opens and shuts as the metal contracts and expands, the heat in the oven can be regulated and kept constantly at the same temperature. The mercury stands at about 292 degrees. There are four doors or entrances to this oven; two in the lower, and two in the upper story. Within the oven is an endless chain, to which arms are attached, and upon which thirty-two forms are laid, about two feet apart. This chain can be moved either by hand or by steam power (the latter being used for convenience and economy in the present case, there being a steam engine on the premises), and revolves perpendicularly through the oven at just that rate of speed as is required to bake the bread with a single revolution; and by means of a conical cylinder, the time of the revolution can be regulated to the fraction of a minute. These thirty-two platforms support thirty-two large bread-pans. Outside, and by the doors of the oven, are two waiting or tender-cars, and all these cars and oven-doors are moved by the same power that moves the endless chain.

"When it is put in motion, one of the oven-doors rises of its own accord, an empty pan trundles out of the oven, and is placed upon the tender-car, by which it is carried to a door on the other side of the oven. A pan containing sixty loaves of dough is placed on this car. The door opposite to which the car is, opens, and the loaded pan at once moves into the oven; the door instantly closes after it, and the pan commences its revolution upon the endless chain. Immediately after the close of this door, the other door opens, and another empty pan moves out, is filled at once with its freight of dough, and then takes its station, like its predecessor at the first door, and follows after in the same manner until the thirty-two cars are filled—the pans always entering at one door and issuing at the other. From the time that all the pans are loaded, a pan of baked bread comes out and dumps itself at one door of the oven as fast as the dough is put in at the other door."

At present the ships of the English navy are supplied with ship-bread, or biscuit, made by machinery, before the introduction of which they were made by hand. In 1833 an apparatus was constructed for this purpose by Mr. Grant, of Gosport. The first process is the preparation of the dough for baking. The meal is conveyed into a cylinder 4½ feet long, 3 feet 2 inches in diameter, and water is let in from a cistern at the back of the cylinder, regulated by a gauge to the exact quantity required for mixing the meal. Through the centre of the cylinder is fitted a shaft armed with knives, and working horizontally. The shaft being set in motion, the knives revolve through the meal and water. During the first half minute the meal and water do not appear to unite; but after this the dough begins to assume a consistency, and in two minutes 5 cwt. of well-mixed dough is produced. The cylinder is formed so that its lower half is easily separated by means of a wheel and pinion from the upper sides, thereby forming a trough containing the dough, from which it is removed, and placed under the breaking-rollers to be kneaded. These rollers, two in number, weigh 1500 pounds each, and are propelled from off a two-throw crank-shaft by means of connecting rods and pendulums; they pass backwards and forwards over the dough during five minutes, when the 5 cwt. of dough is brought into a solid, perfect, and equal consistency. From the breaking-rollers the dough is cut into pieces 18 inches square, and placed on boards 6 feet long by 3 feet wide, which are conveyed, by means of a line of friction-rollers connected by an endless chain, under a second set of rollers, to be rolled to the required thickness of the biscuit. The square of dough being thus pressed out, so as to cover the surface of the board on which it is transferred under the cutting and stamping-plate, is at the same moment cut and stamped, *or docked*, into 42 hexagonal biscuits, which, being now complete, are at once conveyed to the oven on carriages constructed for the purpose. The hexagonal shape is preferred in order that there may be no waste, the sides of each biscuit fitting accurately into those adjoining. The hexagonal cutters do not completely separate the biscuits, so that a whole sheet of them can be put into the oven at once, and, after being withdrawn, they are broken asunder by hand. The grain for the biscuits is prepared at the Government mills; it is a mixture of fine flour and middlings. The ovens are of wrought iron, with an area of 160 square feet. About 112 lbs. weight of biscuits is put into the oven at one time; this is called a suit, and is reduced to about 100 lbs. by the baking.

The bake-house at Gosport was provided with one mixing machine, two breaking-rollers, four sheet-rollers, and four stampers; and it was calculated that this machinery would require eight men and eight boys to supply the nine ovens; that the produce per hour would be 10,000 biscuits, or one ton of bread, at a cost for labor and other incidental expences of 5¼d. per cwt. It was found, however, in practice that the machinery could easily supply eighteen ovens, should it be advisable to enlarge the works to that extent. With the exception of the men employed in heating and managing the ovens, no professional bakers are required, ordinary laborers and boys being fully competent to every other part of the work.

M. Lecompte De Fontainemoreau, of Finsbury, has patented certain improvements in apparatus for kneading and baking bread, &c. The "apparatus for kneading" dough consists of a semi-cylindrical trough, within which is placed longitudinally an axis or shaft, to which are attached on the opposite sides two rows of radial arms, the arms on one side of the shaft being placed opposite the spaces between those on the other side. The ends of the arms of each set are connected together by rods parallel to the shaft which carry short arms projecting inwards, and placed between the long arms. The shaft is driven by a winch handle, and the action of the arms when it is in motion, effectually kneads the dough contained in the trough. The "apparatus for baking" consists of a circular oven provided internally with a revolving table, on which are placed the articles to be baked; and which table is made to rise or fail, as may be required, to change the temperature. The bottom of the oven is heated by

tubular flues, under the movable table; the sides by vertical flues, which lead from the fire-place to the top of the oven, where space is left for the heat to circulate over the whole of it. Above the top flue, which is formed by two plates of metal, the oven is covered with earth, except at one part, where is fixed a receptacle to contain water for the service of the kneading apparatus; such water being heated by the flames, &c., passing through the flue on the top of the oven. A thermometer applied to the exterior shows the degree of heat, and dampers are provided for its regulation.

The following improvements in bread and biscuit machinery are patented by Mr. Exall, of Reading. For kneading flour into dough he uses a hollow screw, or spiral bar of iron, revolving in a cylinder or tube. The materials to be kneaded are supplied by a hopper at one end of the cylinder, which is horizontal, and forced out at the opposite end through a mouth-piece of any suitable form of orifice. The kneaded dough, previously passed through a pair of roughing rolls, is placed on a feed-table, and supplied in a sheet of any desired thickness by a pair of rollers to a travelling web, which carries it successively under the operation of marking or stamping dies, and cutters, having a reciprocating vertical motion, by which the dough is stamped and cut into the form of biscuits, which are then transferred to the oven. When the biscuits are round and cut to waste from the sheet of dough, the apparatus is so arranged as to separate the detached fragments, and prevent their going into the oven with the rest.

A new form of oven is used, in which the baking is effected in the interior of a series of horizontal tubes, set like gas retorts above a fire, or in a flue, and open at either one or both ends, but provided with suitable doors for keeping the same closed during the operation of baking.

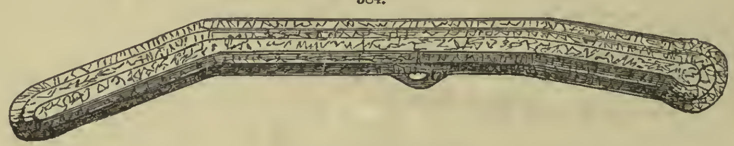
BREAKWATER. A kind of artificial embankment, dike, or rampart, formed of large stones, and erected for the purpose of protecting the entrances of harbors, also roadsteads, from the effects of violent winds, by breaking the force of the waves of the sea; the shipping, moored behind them, lying perfectly secure.

The most celebrated works of this description are those of Cherbourg, in France, and Plymouth, in England.

That of Cherbourg was the first executed, having been begun in the year 1783: the building of the wall was commenced upon upright cones of timber, and each cone was intended to have been about 150 feet diameter at the base, 60 feet at the top, and about 60 or 70 feet high, the depth of water at spring-tides, in the line in which they were sunk, varying from 56 to 70 feet; they were also intended to have been filled with stones to the top, and after allowing some time for settling, the masonry was intended to have been commenced upon them; but a few of these cones only were constructed, when, in consequence of the difficulty of the undertaking, the whole was covered with large stones, thrown in at random. This breakwater is 10 feet above the highest tides, and has a roadway or platform 20 feet wide on the side next the shore, a parapet-wall being built upon it on that next the sea.

The Plymouth breakwater was commenced in 1812. It is composed of blocks of stone, 1½ to 2 and 3 tons weight, and consists of a central part, 1000 yards long; and two wings, each 350 yards long,

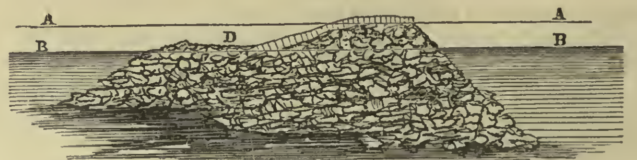
584.



Plan of Plymouth Breakwater.

directed towards the sea, and forming angles of 158° with the centre portion. A transverse section taken through the breakwater shows an average base of 290 feet, and the breadth at the top is 48 feet, with an average depth of water, at low spring-tides, of 36 feet; the side next the sea is sloped in the

585.



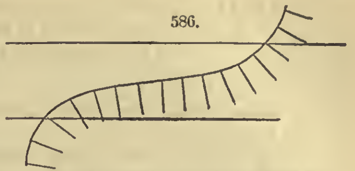
Section of Plymouth Breakwater.—A A, high-water spring tides. B B, low-water spring tides. D, the fore-shore.

proportion of 1 perpendicular to 7 horizontal, and the side next the land is 1 to 5; these sides were not intended, originally, to have had so great a slope, but, in consequence of the violence of the waves during its construction, it was thought proper to increase them, as executed.

The stone was raised in large blocks, some of which contained 10 tons, and were thrown into the sea, in the direction set out for the breakwater, care being taken that the greater number were deposited upon the outer slope. After a number of these large masses had been lowered, a smaller class of stones, quarry rubbish, rubble, and lime-screenings, were thrown in to fill up the interstices, and close all the cavities; these found their position, by the action of the sea, and the great mass became, as it advanced, perfectly wedged together.

BREAKWATER. Fig. 586 represents a form often given to the pavement of the glacis or sea slope of a breakwater. The stones should be of sufficient size to resist the action of the sea.

586.



Section showing the Breakwater Glacis.

BREAST. In mining, the face of coal-workings.

BREASTS. The name given to the bushes connected with small shafts or spindles.

BREAST WALL. A wall built up breast-high, as a parapet-wall, or a retaining-wall, placed at the foot only of a slope.

BREAST WHEEL. A water-wheel which receives its motion from a stream of water flowing on to the breast or side of it, and then descending, bears by its weight upon the lower part of the wheel. See Water-Wheel.

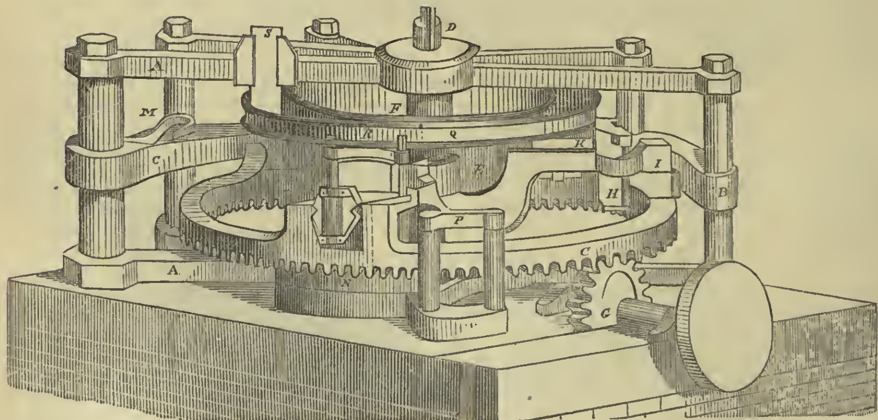
BRICK. An artificial preparation of clay, sand, and ashes, burnt in a kiln, or clamp, and used for building, and for other purposes; good brick earth is also sometimes found in a natural state. A good brick is about 8¾ inches long, 4¼ inches wide, and 2½ inches thick, when burnt.

Bricks appear to have been used for architectural purposes at a very remote period, as we learn from the Scriptures that the Israelites were employed to make bricks in Egypt; and some of the most durable of the Greek and Roman monuments which have come down to us, are wholly, or in great part, constructed of this material. In the East they bake their bricks in the sun; the Romans used them crude, only leaving them a long time in the air to dry, about four or five years. In modern times, brick-making is nowhere carried to greater perfection than in Holland, where most of the floors of the houses, and frequently the streets, are paved with excellent and very durable bricks. Loam and marl are in England considered the best materials for bricks. The former is a natural mixture of sand and clay, which may be converted at once into bricks; marl is a mixture of limestone and clay in various proportions. The neighborhood of London is remarkably adapted for the making of bricks, the soil of the whole surrounding country being clay at a certain depth, generally below a bed of gravel, and the bottom of the Thames yielding the sand which is used in this manufacture; but great practical carelessness seems to pervade the whole business as conducted there. The following is a description of the process as it is usually conducted around the metropolis: The earth is dug up in the autumn, and suffered to remain in a heap until the next spring, that it may be well penetrated by the air, and particularly by the winter frosts, which, by pulverizing the more tenacious particles, greatly assists the operations of mixing and tempering. In making up this heap for the season, the soil and ashes, or sand, are laid in alternate layers or strata, each stratum containing such a thickness as the stiffness of the soil may admit or require. In tempering the earth, much judgment is required as to the quantity of sand to be thrown into the mass, for too much renders the bricks heavy and brittle, and too little leaves them liable to shrink and crack in the burning. The addition of sea-coal ashes, as practised about London, not only makes it work easy, but saves fuel, as when the mixture is afterwards sufficiently heated these bricks are chiefly burned by the fuel contained in the clay. When the brick-making season arrives, the heap is dug up, the stony particles carefully removed, and the mass properly tempered by a thorough incorporation and intermixture of the materials, with the addition of as little water as possible, so as to form a tough viscous paste. If, in this operation, too much water be used, the paste will become almost as dry and brittle as the soil of which it is composed. In order more effectually and regularly to mix the loam and ashes, it is now generally performed in a sort of mill, named a pug-mill. This consists of a large tub or tun, fixed perpendicularly in the ground, and having an upright bar, fitted with knives, placed obliquely. The upright bar is turned by a horizontal lever, to which a horse is attached, and the soil being put in at top, is, by the revolution of the knives, forced through a hole in the side of the tub near the bottom, whence it is removed to the mould-table, which is placed under a moveable shed, and is strewed with dry sand. A girl rolls out a lump somewhat larger than the mould will contain. The moulder receives this lump from the girl, throws it into his mould previously dipped in dry sand, and with a flat smooth stick about 8 inches long, kept for the purpose in a pan of water, he strikes off the overplus of the soil; he then turns the brick out of the mould upon a thin board rather larger than the brick, upon which it is removed by a boy, who places it on a light barrow of a particular construction, which being loaded with a certain number of bricks, they are sprinkled with sand, and wheeled to the hacks. The hacks for drying are each wide enough for two bricks to be placed edgewise across, with a passage between the heads for the admission of the air, to facilitate the circulation of which the bricks are usually laid in an angular direction. The hacks are usually carried eight bricks high; the bottom bricks at the ends are usually old ones. In showery weather the hacks must be carefully covered with wheat or rye straw, unless sheds or roofs be built over the hacks, as is done in some parts of the country, but in London this is impracticable, from the very great extent of the grounds. In fine weather the bricks will be ready for turning in a few days, in doing which they are reset more open than at first, and in six or eight days more they will be ready for burning. In the vicinity of London bricks are commonly burned in clamps. In building the clamps, the bricks are laid after the manner of arches in the kilns, with a vacancy between every two bricks for the fire to play through. The flue is about the width of a brick, carried straight up on both sides for about three feet; it is then nearly filled with dry bavins or wood, on which is laid a covering of sea-coal and cinders, (or, as they are termed, *breeze;*) the arch is then overspanned, and layers of breeze are strewed over the clamp, as well as between the rows of bricks. When the clamp is about six feet wide, another flue is made in every respect similar to the first. This is repeated at every distance of six feet throughout the clamp, which, when completed, is surrounded with old bricks, if there be any on the grounds, if not, with some of the driest of the unbaked ones reserved for the purpose; on the top of all, a thick layer of breeze is laid. The wood is then kindled which sets

fire to the coal; and when all is consumed, which will be in about twenty or thirty days if the weather be tolerable, the bricks are concluded to be sufficiently burned. To prevent the fire burning too furiously, the mouths of the flues are stopped with old bricks, and the outside of the whole clamp plastered with clay; and against any side particularly exposed to the rain, &c., screens are laid, made of reeds worked into frames about six feet high, and of a width to admit of being moved about with ease. This is the mode of manufacturing the ordinary descriptions of bricks; but the superior sort, termed *washed malms* or *marls*, are tempered with greater care and attention. For this purpose a circular recess is built about four feet high, and from ten to twelve feet diameter, paved at bottom, with a horse-wheel placed in its centre, from which a beam extends to the outside for the horse to turn it by. The earth is then raised to a level with the top of the recess, and forms a platform for the horse to walk upon. Contiguous to the recess a well is formed for supplying the recess with water, which is raised by a pump worked by the horse-wheel. A harrow made to fit the interior of the recess, thick set with long iron teeth, and well loaded, is chained to the beam of the wheel to which the horse is harnessed. The soil prepared in the heap in the usual manner is brought in barrows, and distributed regularly round the recess, and a quantity of chalk is added, and a certain portion of water; and the horse being set in motion, drags the harrow, which forces its way into the soil, admits the water into it, and by tearing and separating the particles, not only mixes the ingredients, but also affords an opportunity for stones and other heavy matters to fall to the bottom. Fresh clay, chalk, and water, continue to be added until the recess is full. On one side of the recess, and as near it as possible, several hollow square pits are prepared about 18 inches or 2 feet deep. The soil, reduced to a kind of liquid paste, is discharged from the recess by a sluice, and conveyed by wooden troughs to the pits. In these pits the fluid soil diffuses itself, settling of an equal thickness, and remains until wanted for use, the superfluous moisture being drained or evaporated away by exposure to the atmosphere. The remainder of the process is the same as for the common sort of bricks. In the country, bricks are always burned in kilns, whereby much waste is prevented, less fuel is consumed, and the bricks are more expeditiously burned. A kiln is usually 13 feet long by 10 feet 6 inches wide, about 12 feet in height, and will burn 20,000 bricks at a time. The walls are about 14 inches square, and incline inwards towards the top. The bricks are set on flat arches, having holes left between them resembling lattice-work. The bricks being set in the kiln, and covered with pieces of broken bricks or tiles, some wood is put in and kindled to dry them gradually; this is continued till the bricks are pretty dry, which is known by the smoke turning from a darkish to a transparent color. The burning then takes place, and is effected by putting in brushwood, furze, heath, faggots, &c.; but before these are put in, the mouths of the kiln are stopped with pieces of brick called *shinlog*, piled one upon another, and closed over with wet brick-earth. This shinlog is carried just high enough to leave room sufficient to thrust in a faggot at a time; the fire is then made up, and continued till the arches assume a whitish appearance, and the flames appear through the top of the kiln, upon which the fire is slackened, and the kiln cooled by degrees. This process is continued, alternately heating and slackening, till the bricks are thoroughly burned, which is usually in the space of forty-eight hours.. Many attempts have been made of late years to supersede, by the aid of machinery, a portion of the manual labor now employed in the manufacture of bricks.

BRICK-MACHINE. Fig. 587 is a representation of Stephen Ustick's, for *Moulding aud Pressing Bricks* from untempered clay

587.



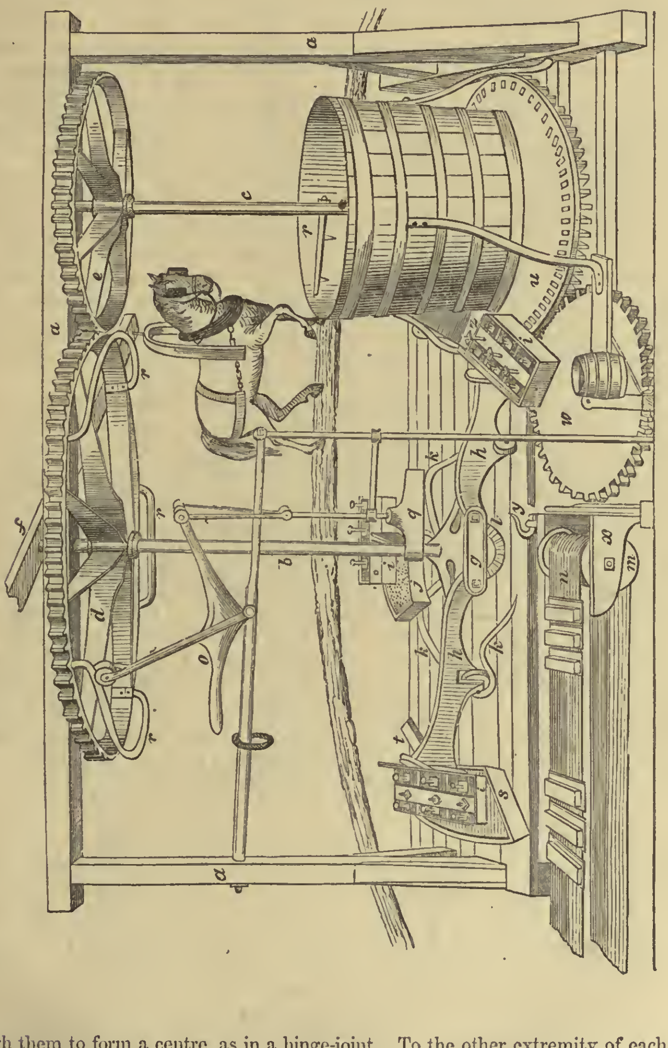
A A, frames, between which the cams B C and the centre shaft D are firmly bolted.
B C, cams which give the pressure to the outer pistons.
D, centre shaft on which the wheel of moulds revolves.
E, cam-wheel on the centre shaft D, which gives the pressure to the inner pistons.
F, cam-wheel on side shaft, above the cam-wheel E, which gives motion to the fillers. The view of this cam-wheel is obstructed by the receiver.
G, the pinion on the driving-shaft.
G, revolving wheel on the shaft D, having pairs of parallel arms to which the moulds are bolted, and between which the pistons slide.
H, the moulds.
I I, pistons which condense the clay.
K, the fillers which supply the moulds with clay.
L, the hoppers above the fillers.
M, a light cam, which brings the outer piston out of the mould after the brick is pressed, while the inner one is thrust through the mould, carrying the brick with it, by a projection of the cam-wheel E.
N, a perpendicular cam which operates the plunger O, to discharge the bricks from the pistons.
P P, cams which bring the pistons into the moulds.
Q, annular receiver, into which the clay falls from the pulverizer.
R, openings in the bottom of the receiver communicating with the hoppers L.
S, scraper which fills the hoppers

After the first pressure is given to the clay, which commences when the outer piston is at the front end of the cam B, the air is let off of the brick by the filer, (the front end of which is a false top to the mould,) moving inwards, leaving the upper part of the brick bare for the condensed air to escape; it then moves back to its place before the piston reaches the back end of the cam C, and then the second pressure is given to the brick, without any loss of time, as a brick is made in each mould in every revolution of the wheel.

From the full explanation of the different parts of the machine, and their functions, and by reference to the figure, it will readily be seen that it is simple in its construction, as all the motions to the pistons and fillers are given by *stationary cams* as the wheel of the mould rotates. The pressing cams give a powerful progressive pressure—the same in effect as that given by toggle-joint levers.

Fig. 588 is a representation of Messrs. Choice and Gibson's brick-making machine, *a a a a* is an upright frame, with cross beams at top and bottom; *b c* are two vertical shafts, carrying two horizontal spur-wheels *d* and *e*, the teeth of which take into one another; these are put in motion by the horse-shaft *f*, or any other convenient power. Near the bottom of the shaft *b*, is fixed a large cast-iron collar *g*, having three deep mortises; into each of these the end of an iron arm *h* is fitted, with a bolt

588.



passing through them to form a centre, as in a hinge-joint. To the other extremity of each of the arms *h* is firmly fixed, by screw-bolts, a cast-iron mould-box *i*, having three divisions for three bricks, in which work three stocks or false bottoms, having upright bolts passing through holes in the top. By the revolution of the shaft, these mould-boxes, with their arms, are successively carried up and over the risers *k k k*, which form circular curves in the plan, and appear so in the perspective, but are in reality

inclined planes. At l, near the bottom of the shaft, is a small bevelled wheel, which actuates a pinion fixed on the spindle of the drum-wheel m that passes under the floor of the machine; an endless strap passing round the drum m, and another placed at the required distance, continually carries the bricks forward to their destination as fast as they are made, and deposited upon it. o is a crank or lever, attached by a joint to the framing, as shown, at the upper end of which is fixed a roller; by the revolution of the wheel above the three circular bars or cams, $r\,r\,r$, attached to the wheel, successively act upon the roller, and depress the crank o, which first raises the rod and weight q, and afterwards, as soon as the crank is relieved of the pressure, allows it to drop and strike the mould-boxes, by which the bricks are discharged out of them. s is a box of cast-iron, containing water, into which the mould-boxes dip; t is a cushion, upon which they next fall in succession, by which the superfluous water is taken off; and j is a box of dry sand, into which the mould-boxes afterwards fall, their surfaces becoming in consequence slightly coated with sand previous to becoming charged with clay. The horizontal wheel e worked by d actuates the shaft c bearing the knives in the pug-mill. At the lower end of the shaft c is fixed the large circular revolving bottom-plate u, the periphery of which being furnished with teeth or cogs, as shown, take into the teeth of a circular revolving plate v, over which, as the mould-box passes, the lower surface of the bricks becomes smoothed. At x is a small frame, working up and down in a casing, with a pulley and counterbalance weight, like a sash window; it is raised by the crank y as each mould-box passes, when three little boards are placed across the frame by a boy, for the reception of the bricks. When these are deposited by the means described, the frame drops below the level of the endless strap n; the latter then receives them, and carries them off to their destination. At z is fixed a flat box, which acts as a gage to regulate the thickness of the stratum of clay revolving upon the bottom plate u of the pug-mill. The operation of this machine is as follows: the clay being worked in the ordinary manner through the pug-mill, it passes out at the mouth, (not shown, being on the opposite side,) from thence under a flap which partly regulates the quantity on the bottom plate, and next under the gage, which determines it precisely. A mould-box having passed over the highest inclined plane or riser k, first falls on the stratum of clay, and chops out three bricks, filling the moulds therewith by the false bottoms rising up to the determined point from the pressure of the clay against them; the moulds, with the bricks in them, then slide over the polishing plate r, (which is kept wet by water constantly dripping upon it from a tub;) from thence the moulds pass on to the frame x, when the weight q strikes against the protruded bolts of the false bottoms, and pushes out the bricks upon the boards on the frame; the frame then descends two or three inches by their weight, and delivers the boards upon the endless strap, which, being constantly in motion, carries the bricks away to be deposited on the hacks. The mould-box being discharged, is then carried upon its roller up the first riser k, drops into the water, thence rises again, falls upon the cushion, next into the sand-box, whence ascending again, the highest inclined plane being duly prepared, it falls again upon the bottom plate of the pug-mill, and chops out three more bricks, during which period each mould-box has operated in a similar manner.

We shall now proceed to describe the brick-making machinery invented by Mr. Leahy, and erected by him for the Patent Brick Company; it is represented in the succeeding figure. a is the main horizontal shaft in direct communication with the steam-engine or other first mover; b is a hopper-formed vessel, technically termed the pug-mill, in which the clay and other materials are tempered and mixed up: it is for this purpose furnished with cross iron bars, or blades of steel; part of these are firmly fixed to the *hollow* vertical shaft c, and the remainder bolted to the sides of the pug-mill, and they are so arranged, that those fixed to the shaft cut in as they revolve between the others. The clay is delivered into the hopper or pug-mill by an endless chain of buckets, (in the same manner as ballast is raised;) it is then cut up and tempered by the knives and bars in the pug-mill, and gradually descending, it falls, or rather is forced by the superincumbent pressure upon the circular inclined plane d, which consists of a single thread or spiral turn of a very large screw, occupying the whole internal space of the lower cylindrical end of the mill, where it is exhibited in section. This screw or circular inclined plane is fixed to the central shaft passing longitudinally the hollow shaft, and a slow reversed motion is given to it, by means of an intermediate wheel acting upon pinions in the upper part of the frame. The blades on the hollow shaft revolve in the pug-mill at the rate of fifteen turns in a minute, grinding and dividing the materials much more completely than in the ordinary mode of brick-making. In this attenuated state the materials are forced upon the circular inclined plane of the screw, and as this slowly revolves in a contrary direction at the rate of five turns in a minute, it takes hold of the clay, (by a peculiar adaptation not easily described,) and forces it out of the mill in a very compact state, into a receptacle below: of this, one side is always in immediate contact with the moulds, and those two sides which are at right angles to the former side are closed by iron cheeks, between which the lever or forcing flap n acts by pressure, and fitting closely, prevents the escape of the clay, so that it can only pass into the moulds. These moulds are placed round the periphery of a circular frame e, made of flat iron rings, fixed upon bars or spokes, and turning upon a *fixed* shaft. There are twenty-five of these moulding-boxes in one circle; but as the frame e may be of any breadth, it may contain twice twenty-five or thrice twenty-five on the circumference of the cylinder, provided that the engine is capable of affording sufficient power or force to cut or mould so many bricks at each revolution. Each moulding-box is furnished with a false or moveable bottom, to which rods are attached, for the purpose of pushing out the brick when moulded, and drawing back the bottom to its place to receive a fresh portion of the clay. The manner in which these operations are performed is extremely simple and ingenious. The ends of each of the moulding-box rods are bent at right angles, and an eccentric piece f is so fixed, that, as the moulds revolve, and at the moment that the surface of each is covered by being in contact with the clay, it gradually draws back the false bottom, and with it the clay, which is also urged on by the circular inclined plane d; and to render the bricks solid and compact, a powerful pressure is applied to them by means of the flap forcer n, to which a backward and forward motion is given by the *thrusting* of a rod attached to a revolving crank. The moulding-boxes, immediately they are thus filled, are subjected alternately to the action of a steel scraper, which

levels and smooths their surface, and is made to operate by the pressure of springs. The bricks, now completely formed and fast in their moulds, pass downwards in their revolution, which brings the ends of the rods under the operation of a cylindrical roller, with grooves made round it at equal distances; into these grooves the ends of the rods successively pass, which, in their revolution, force out the rods, and thereby push out the bricks from the moulds on to boards placed underneath to receive them. The bricks thus made are carried forward to the hacks or drying-house, upon an endless web or chain *i i*, to which a continued motion is communicated by the revolution of the two polygonal drums or wheels *k k*, placed at the requisite distance asunder. The upper part of the engraving shows a side elevation of the machine, and the lower part a section of it; and although these views serve to give a general idea of the construction of the apparatus, it has been impracticable to show the gearing by which the

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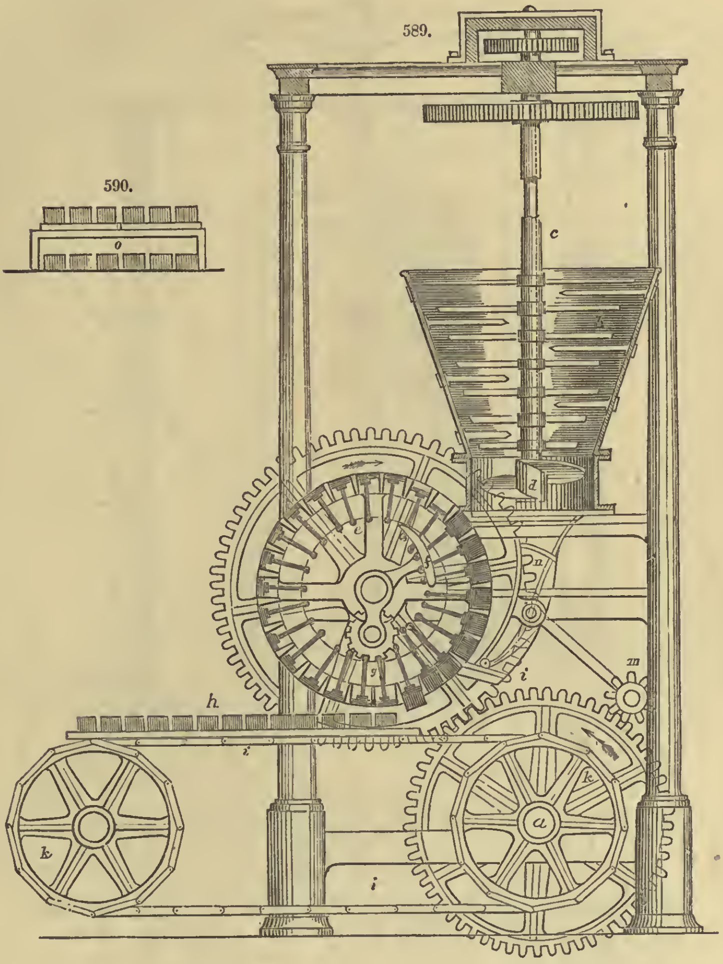

590.

several motions are produced; we will therefore attempt to describe it as follows:—Upon the horizontal shaft *a*, (which makes 2½ revolutions per minute,) is fixed a toothed, bevelled wheel, which drives a bevelled pinion on an upright shaft, (not shown;) nearly at the top of this a spur-wheel is fixed, which works into a pinion fixed upon the upper end of the hollow shaft *c*, which carries the knives or blades in the pug-mill. Upon the upper end of this upright shaft is also fixed a pinion, which works into an intermediate pinion turning upon an axis. This intermediate pinion acts upon another pinion affixed to the internal shaft, communicating a slow and reversed motion to it, and also the circular inclined plane affixed to it; at the lower end, on the main horizontal shaft, is fixed a spur-wheel *m*, which gives motion to the crank and to the flap forcer connected to it. *o*, in the separate figure, gives the form of the shelves comprising the drying apparatus,—Mr. Leahy proposing to dry bricks either by flues or by steam, instead of ranging them in hacks exposed to the variations and inclemencies of the weather,—by which means it is presumed that the bricks will be rendered dry enough for burning, either in kilns or clamps, in a much shorter time than in the common method, and the process may be carried on in winter as well as in summer. If drying by flues be resorted to, a drying-house must be furnished with proper stages, and shelves must be provided. Around and across the lower part of these, flues framed

either of bricks or cast-iron are to be placed, through which flame or heated air is to be conveyed. In drying by steam, the vapor is conveyed from the boiler through cast-iron pipes throughout the drying-house, and boards are arranged upon stages, (similar to those in Fig. 590.) so as to leave intervals between the rows of bricks, and to prevent their touching one another.

Nash's Patent Brick-making Machinery.

This invention, which we have now to describe, is not the only one, we believe, that has been brought into successful operation. The leading features of Mr. Nash's mechanism consist in the application o

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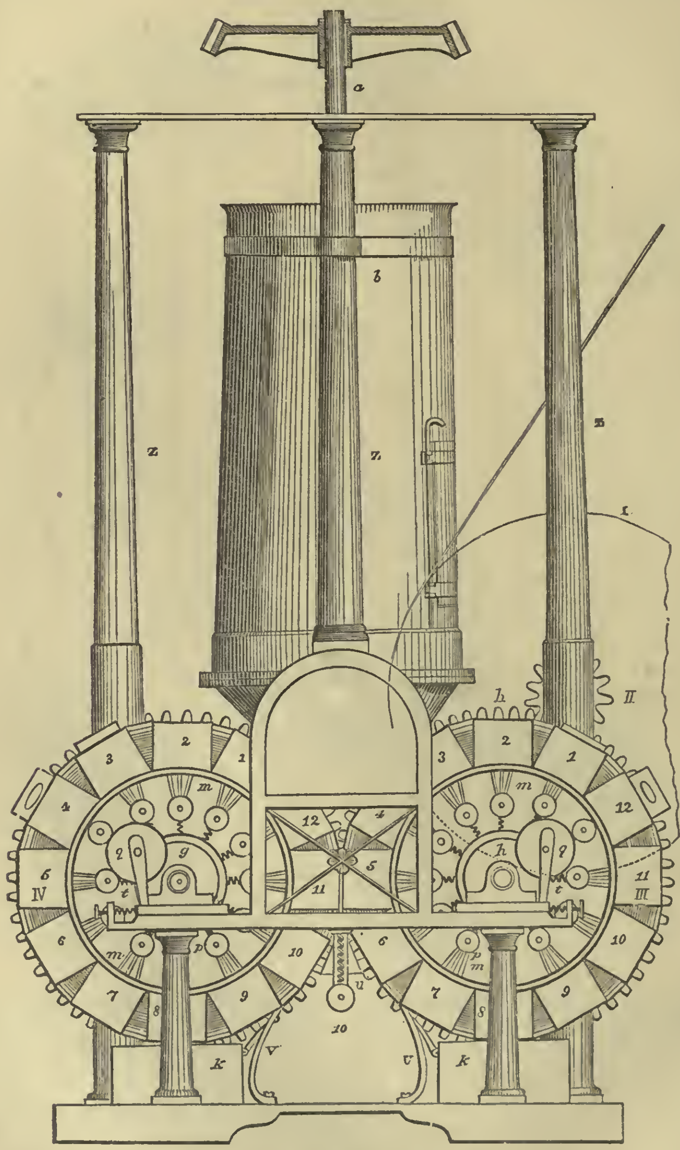

separate or detached moulds of a particular construction to a series of mould-boxes, which are consecutively brought into action; in the employment of heaters, placed in contact with, or contiguous to, the fresh bricks, during the process of their being moulded; and in lieu of sand, which is generally used to prevent the adhesion of the bricks to the moulds, employing elastic absorbent substances, such as cloth saturated with water. In the subjoined engravings, Fig. 591 represents a front elevation, and Fig. 592 an end elevation of the principal parts of the machine. A vertical shaft *a* is made to revolve in the cylinder or pug-mill *b*, by any adequate force acting upon the bevelled wheel *c*. A number of broad

steel or iron blades *d d d* are attached to the shaft *a*, their surfaces being set at such an angle as will cause them, during their revolution, to pass nearly in contact with the edges of two other sets of knives *e e e*, fixed on opposite sides of the cylinder, by which means the clay and other materials with which the mill is charged are tempered and amalgamated, and then forced into the hopper *f*, fixed to the lower extremity of the pug-mill. This hopper is divided into two equal chambers by a vertical blade or knife, which separates the materials into equal portions, which are supplied to the moulds in a compact state. The moulds are lodged in rectangular cavities at equal distances in the periphery of two polygonal drums *g h;* these cavities are marked 1 to 12. To one face or side of the drums are attached two toothed wheels, gearing into each other so as to revolve in opposite directions when motion is communicated to one of them. These wheels lying at the back of Fig. 591 cannot be seen, but one of them is shown at *i* in Fig. 592. The moulds, after being filled with the plastic material, are pushed out from their recesses by means of pistons at *m m*, easily fitting the recesses, and sliding upon parallel rods fixed to the rims of each drum. To each piston is attached, by a short rod, a cross-head, sliding upon the parallel rods, and having at each end small anti-friction wheels *p p*, which, by the motion given to the machinery, come in contact with a larger wheel *q*, placed eccentrically, which thus raises the pistons, and the moulds which lie upon them are then removed by hand and emptied. During this latter process the emptied mould-receiver will have passed over the centre of the eccentric wheel *q*, and the piston will be descending when the attendant places the emptied mould in its former situation, to be filled again from the hopper as it passes under it. Between each of the rectangular mould-boxes are formed a series of wedge-shaped boxes, termed by the patentees "hollow sectors," into each of which is placed a red-hot iron, the object of which is to expel the superfluous moisture from the newly-formed brick, &c., in order that the manufacture may be conducted in the winter as well as the summer. These irons are heated in the kiln-fires. The axis of the polygonal drums revolve in plummer-blocks, supported upon a strong frame *s;* but as the polygonal drums revolve in close contact, the plummer-blocks are free to slide in grooves in the frame, and the wheels are kept in contact by the action of strong helical springs *t*, which press against the plummer-blocks, the other end of the springs abutting against a regulating screw. In the middle of, and underneath the horizontal frame *s*, is fixed a knife *u*, (supported in its place by a spiral spring,) which separates the whole or a portion of the superfluous materials from each mould, as the latter passes over the edge of the former. As some redundancy of material may still be left after the operation of the knife *u*, the exposed surface of the moulds in motion undergoes a similar treatment from two other knives *v v*, fixed to the foundation plate *w* of the machine. A trough or cistern *k k*, containing water, is placed under each of the drums, the lowest sides of which come in contact with a cylinder *y*, covered with strong coarse cloth or other suitable absorbent substance, which, as it revolves, takes up the water and delivers it to the moulds as before mentioned. These cylinders are mounted on elastic bearings, and derive their motion from pinions on their axes, actuated by the toothed wheels on the drums. In the centre of the foundation plate there is a cavity, or pit, for the reception of the superfluous clay or other materials, which are removed at pleasure. The pug-mill has a door in it, for the convenience of cleaning it out when requisite; and the whole of the upper part of the machine is supported by three columns

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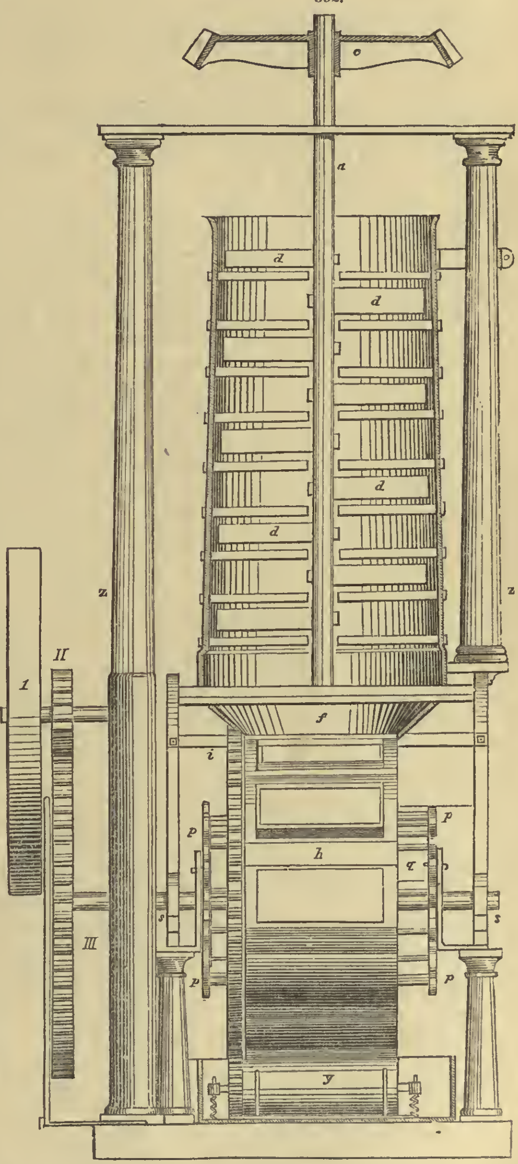

zzz. The polygonal drums are driven by a set of wheels lying at the back of Fig. 591, and therefore in that figure shown by dotted circles. No. I. is a band-wheel, which drives, by a pinion II, the two wheels III and IV, on the axes of the driving gearing, into each other, and turning in opposite directions. Those two wheels must have involute teeth, as their point of contact becomes variable by the movement of the axes of the drums. In case of negligence on the part of the boys, or other attendants of the machine, in not removing the bricks or tiles after the moulds containing them have passed the centre of the eccentric wheel, they fall back into their former position, and pass round to the place of delivery, as before, without any damage whatever being done to the machine.

Having explained the general arrangement and operation of the machine, there remains to be described the construction of the detached moulds. Fig. 593 represents a side view, and Fig. 594 an end view of one of these. The ends of the mould 18, 18, are made of wood, plated at the edges with iron, and fastened on by screws, as seen in Fig. 593. The bottom 19, is also of wood, but cased in a strong frame of cast-iron, and its two extremities are jointed to the ends 18, 18, so as to open only a little way, for allowing the brick to separate freely from it upon inverting the mould.

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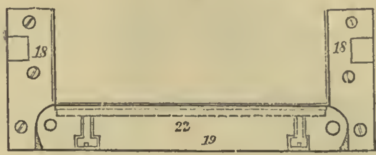

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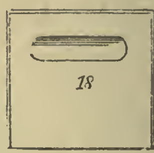

This effect is facilitated by lining the interior of the mould with cloth, which, although constantly in a wet state, admits air to pass through its interstices when the clay is forced into the mould, so that when the brick is afterwards forced out, the moisture of the cloth, and the spring of the confined air, delivers the brick uniformly clean, without the adhesion of any clay. It will be observed that the two ends 18 of the mould have each a cavity; these cavities receive the fingers of the workman when he takes hold of the mould, which he afterwards inverts, drawing back the ends 18 at the instant, and pressing with his thumb upon the screw-heads 21, 21, the other ends of which are attached to a plate 22 underneath the cloth lining of the bottom, as shown by dots, causing the brick to be immediately disengaged. The two sides of the brick not included in the detached mould are formed by the partition between the mould-boxes and the hollow sectors. The forms and dimensions of the detached moulds are varied according to the nature of the articles to be produced therefrom. For adapting the machine to make tiles, or other articles of a greater length than a brick, two moveable blocks, which usually lie inside the hopper, to contract its lower dimensions, are taken out. In the making of drain tiles, and other articles having cavities within them, jointed horses or cores are employed; the plastic matter is forced around them by the action of the machine in the same manner as in forming a brick, and the subsequent operations are also the same, except that in the removal or delivery of such tiles from their moulds, suitable adaptations are made to prevent their being pressed or even touched by the hand. The annexed Fig. 595 exhibits another arrangement employed by Mr. Nash for making flat tiles, flooring tiles, &c., of any required breadth and thickness. This cut only represents the lower part of the machine, the upper being the same as in the previously-described apparatus. To the bottom of the pug-mill is fixed a funnel-shaped hopper 23, the materials in which, after being forced through a mouth 24, formed of the required shape, are received upon boards 25, and when cut to the proper length, are removed to sheds for drying. In order to equalize the surface of the clay after it has come out of the hopper, a roller 26, turning in bearings on a curved arm, which is fixed to a hinge-joint, gives to the material any pressure that may be required, by loading it accordingly. The dotted lines 27, 27, in the same figure, exhibit another funnel-shaped hopper, for the purpose of making pipes or tubes, by means of a centre core 28, between which and the cylindrical continuation of the hopper, the material is forced by the action of the pug-mill, and produces a tube, which, after having made a certain length of, is cut off, the tube being turned round, to render the inside smooth previously to its being removed. The patentee states that this machine may be used with either one or two horse power; that when used with one horse power, the product is about 700 per hour, or 8000 per day; to do which requires the services of two men and eight boys, occasioning an expense not exceeding two shillings and

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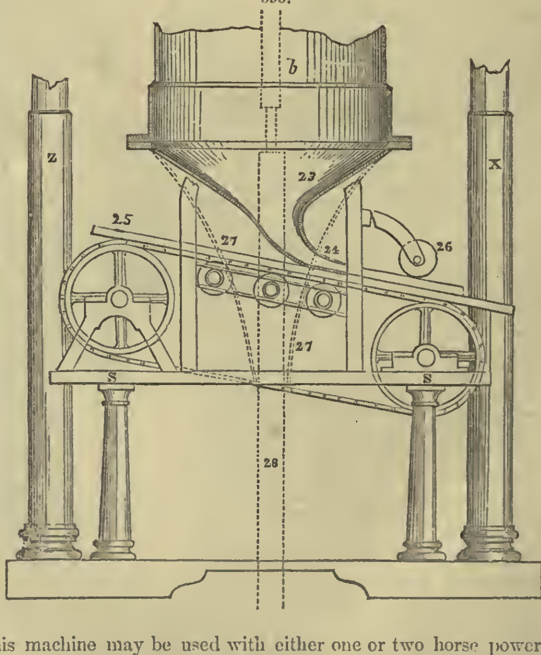


sixpence per 1000. With two horse power employed, the production is double, or 16,000 per day; but the quality of the bricks, which the editor has seen, is equal to those which are usually finished by grinding the surfaces by hand. The saving of labor in the production is about two shillings per 1000; but the quality rendering them worth five shillings per 1000 more in the market, the advantage of making by the machine, where good bricks are required, is equal to seven shillings per 1000.

BRICKS AND TILES, *Machinery for the manufacture of.* The application of machinery to the fabrication of bricks has met with considerable opposition in the diversity of physical and chemical conditions of the earths used. Thus, in some localities the clay has more tenacity and aluminous properties than in others; the mechanical powers sufficient for the last would be useless in the first.

As early as 1835, M. Terrasson had constructed a machine surpassing all previous ones in simplicity A frame, having wires stretched across, cuts into bricks the earth which has been compressed between a roller and planks.

M. Carville has invented a machine which simultaneously bruises and divides the earth, moulds and throws off the bricks; it may be applied to the fabrication of tiles and other earthen ware.

Description of M. Carville's Machine, Figs. 596 to 604.

Division and kneading of the Earths.—The earths used are clays, requiring sometimes sand or aluminous compounds. The mixture is the most difficult part in all the process of brick-making. To this end M. Carville uses a cylindrical barrel A, with a flat bottom; its upper part is opened in order to introduce the material. An axis B, also vertical, to which a rotary motion is imparted by a horse harnessed to the beam C, through the medium of the cast-iron socket *a*, (see Fig. 596, which is a vertical section through the middle of the machine.) This axis rests against two pillows, one adapted to a beam *b*, which unites the opposite sides of the machine, and the other upon an inferior cross-beam. This axis is provided with several flat iron branches *d*, which being fixed perpendicularly to the axis, their faces have an inclination of 45°. On these there are sharp-edged knives, to divide and knead the clay during their rotation; thus the earth is well divided before reaching the inferior part of the barrel. The branches *e f*, stouter than the former, but without knives, are attached at the very extremity of the axis, and receive from it a rotary motion, during which they press against the earth, forcing it out through the orifice *g*. The size of this orifice depends on the quantity needed to fill the moulds; the iron sliding-door *h* regulates this orifice.

This method for dividing and kneading is applied to the fabrication of earthen ware, porcelains, etc.

Moulding and casting off the Bricks.—It is specially in these functions that M. Carville's machine excels all others. He uses a series of moulds in cast-iron, forming an endless chain D, constantly moving; these moulds successively pass beneath the aperture through which the moistened earth is pressed, in order to receive it. Each link forms a rectangular frame, composed of four moulds, which have the precise dimensions of the bricks. Figs. 597, 598, 599, show a plan and transverse section of this chain.

Two wheels, with each four arms E, are situated on either side at the extremity of the apparatus. The iron bars *i* support the limbs and impart to them the movement of rotation communicated by the spur-wheel F; the arrows indicate the direction in which they are to move Fig. 596, so that the moulds are carried under the roller G after they are filled with earth.

This roller is of cast-iron, turning round a horizontal iron axis, set in motion by the beam C. Its office is to compress the earth in the moulds as it is received from the barrel. But as these moulds have no bottom, a moveable flooring is adapted to them to serve as such; it is made of strong sheet-iron *j*, the pieces approaching each other at distances proportional to the length of the bricks, and hooked to an endless chain passing over the rollers *k*; one of these rotates, giving to the chain a motion equal to the speed of the moulds. These must be nearly horizontal, when they pass beneath the barrel; to give them this direction, a number of wooden rollers H support the iron plates. The axes of these rollers are of iron, freely turning on pillows, Fig. 600.

The clay being thus moulded and pressed, soon meets the blades *l*, made of steel or cast-iron, which shave the two horizontal and parallel faces of the moulds, levelling and polishing the bricks.

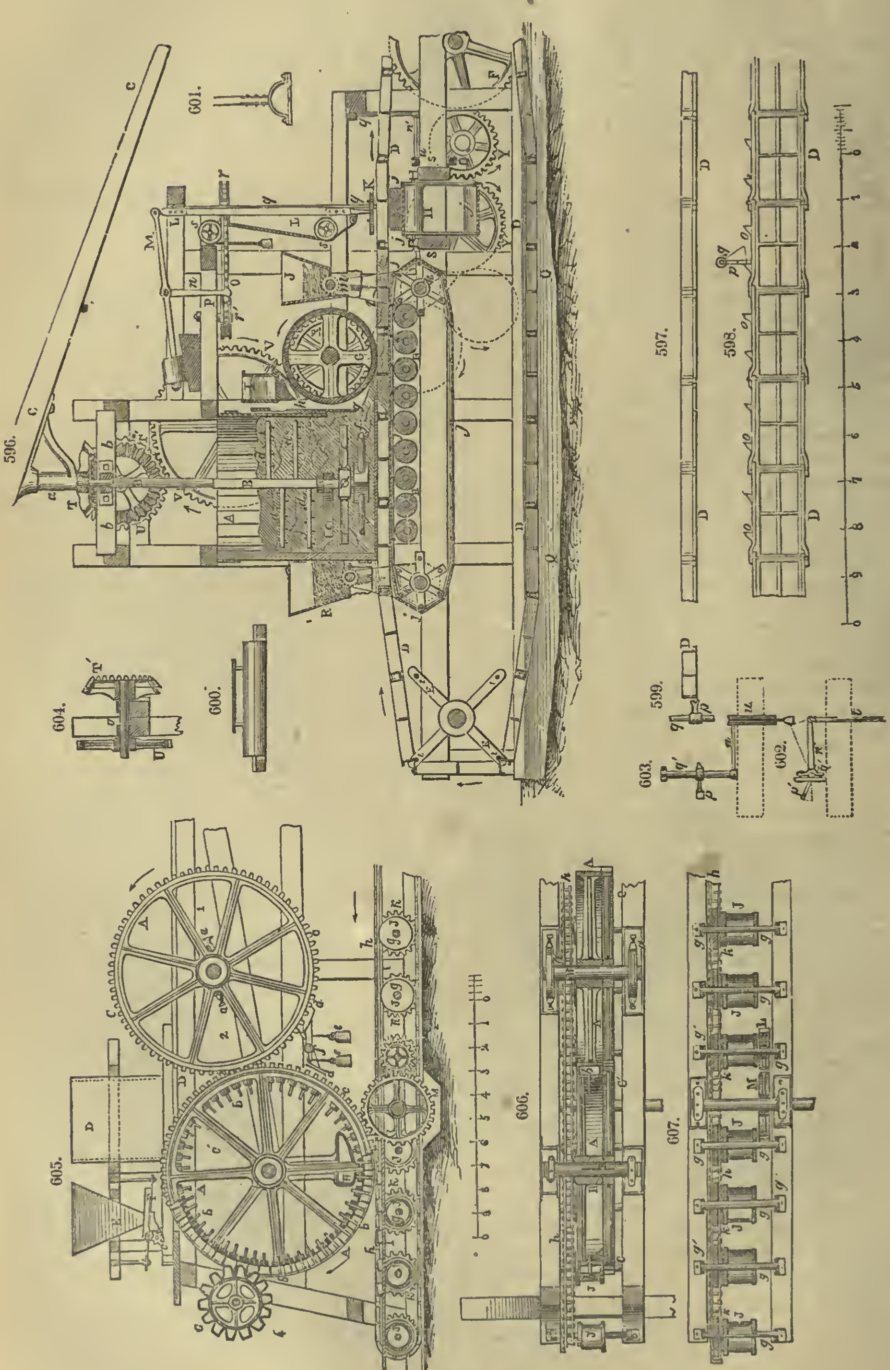
The clay is prevented from adhering to the surface of the rollers by the water slowly falling from the vessel I.

A wooden hopper J, containing fine and dry sand, sprinkles the bricks as they pass beneath *l*; a small fluted cylinder *m*, is adapted to the base of the hopper to allow the sand to come out—but in small quantity; this cylinder is rotated by means of a pulley and strap, or a small endless chain.

As soon as the bricks have passed the polishing blades, they are taken out of the moulds. This is ingeniously done by the simple process of M. Carville. Two pieces of cast-iron K, having a superficial dimension equal to that of the section of the mould, which they completely fill, are attached to a single vertical beam L, which is suspended to another beam M, the other extremity of which being balanced by a counterpoise, this is prevented from falling by a board N.

To the axis of the beam M a vertical branch *n* is adapted; this receives a movement of oscillation, depending on the speed of the endless chain of moulds. To this end, this last is provided with little knobs *o*, Fig. 598, which meet and push successively a horizontal lever *r*, Fig. 599, fixed to the vertical axis *g*. To the superior part of this axis is attached the pulley *r*, Fig. 596, to the circumference of which is hooked the small chain O, whose other extremity is fastened to the pulley *r'*, freely rotating round the iron pin P.

Thus when one of the knobs *o* is in contact with the inferior lever *p*, it pushes it in the direction of the chain, causing the vertical axis *q* to turn; the pulley attached to *q* turns also, carrying along the chain O, and since the extremity of the vertical branch *n* is engaged in one of its links, it is drawn by it: therefore the axis carrying it oscillates, and also the beam M; L descends, pushing the lumps K into the two corresponding moulds, thrusting the bricks on a moveable floor *j'*. The weight attached to the beam M causes L to rise, as soon as the lever is no longer acted on by the eminence *o*.



596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607.

To bring back to its original position the beam L, a cord is attached to its lower extremity, passing through the pulleys $s\,s'$, and having a small counterpoise fastened to its other end.

The chain, going all the time, plunges into a reservoir of water Q, which extends its whole length, to wash the moulds. Following the direction indicated by the arrows, it passes under the hopper R, where the moulds are sprinkled with sand before reaching the barrel.

The second moveable flooring j', which receives the bricks, is composed of small plates forming an endless chain; parallel rollers, such as H', placed in a different direction from the first, support this chain. Their iron axes are moveable in pillows resting against oak beams S.

This flooring moves only when the beam L rises. The teeth o raise successively a short lever p', which is attached about the middle of the short vertical axis q'; to this is adapted a second lever n', fixed to a small horizontal beam t, which communicates through a rope with the pulley u. Thus, as soon as a tooth acts on p', its axis oscillates, and its inferior lever n forces the flooring j' to advance a distance equal to the breadth of the two bricks. The small rope passing through u has a counterpoise to bring back the levers to their original position.

The bricks being taken off without any handling, are put up to dry. The plates are set back to the chain j', on the side opposite to that on which the bricks were.

Description of the Machine of M. Capouillet, Figs. 605, 606, 607.

This machine consists of two cast-iron cylinders, performing the office of rollers; one is perfectly smooth, the other is pierced over all its surface with cavities, the dimension of which depends on the size of the bricks to be made: pistons are made to fit into these cavities. These pistons receive an alternative movement equal to the thickness of a brick.

Construction of the Cylinders.—The first cylinder A is solid and smooth; its diameter is 7·31 feet, and its breadth is 7·47 feet. It has an axis of wrought-iron B, turning in pillows with screws a. It receives its motion from the second cylinder, through a straight-toothed wheel C, whose inner diameter is precisely that of the external cylinder.

The second cylinder A' is of the same dimensions with the first, but whose circumference contains a great number of rectangular cavities, having only 0·039 feet between each, and of sufficient depth to contain each the thickness of a brick and of a metallic piston b. It has also a horizontal axis of wrought-iron B', of equal length with the preceding. It also is provided with an axis C' of equal diameter with C, with which it is engaged; the pinion M communicates motion to it.

The pistons b are rectangular, their dimensions in length and breadth being equal to the bricks; they are free in the cavities, but closely fitting: a cylindrical rod is attached to them.

Moulding the Bricks.—The clay being prepared, is brought into a rectangular box D, extending as far as the two cylinders, between which the earth falls and is carried away by them. The quantity is regulated by a slide adapted to the box, whose height must not be less than 6·50 feet. By its side is placed a hopper E, containing dry fine sand to be sprinkled on the cylinder A' before the earth enters its cavities. The spout F regulates the direction of the sand; to it an oscillating motion is imparted by the spokes c.

The clay, falling between the two cylinders from the box D, is pressed into the cavities of A', filling them in succession with so much more ease as the pistons are pushed in. These pistons had previously been forced in by the cog, which is furnished with the circumference of a strong cast-iron disk G, situated at the right of the cylinder, and having an iron axis. These cogs are disposed as in a cog-wheel, and engaging into the cavities of the cylinder, they push the pistons within the cylinder.

An eccentric of cast-iron H is contained within A', freely turning round on its axis, in order to force the pistons from within out, thus forcing the bricks away. The curve of this eccentric must be calculated to give the pistons play only the thickness of a brick. Fig. 605 gives an external elevation of the apparatus, and also a part of the vertical section, showing the disposition of the pistons.

Two scrapers $d\,d'$, adapted to iron levers, which oscillate round the common axis f, and which have counterpoise $e\,e'$, serve to keep the surface of the cylinders smooth and clean.

Transportation of the Bricks.—The horizontal boards I, receive the bricks as they are forced out of the moulding cylinder; they are moved with a speed somewhat greater than the cylinders, in order to leave a small space between the bricks. Their direction is from left to right.

These boards are carried by small cylindrical rollers J of cast-iron, the axes of which rest on collars g', pinned on the sleepers, as seen in the horizontal section, Fig. 607. The toothed-wheel k, in which an endless chain h is engaged, transmits to them the motion communicated to it by the wheel which is placed on one of the rollers, to which the small pinion L is adapted. This last is engaged in the principal pinion M, whose axis is turned by the prime mover which may be a hydraulic wheel, a steam-engine, or a horizontal beam turned by a horse.

Two brick-making machines much in favor in England, are Ainslie's and Hunt's. The latter has been extensively used in the execution of large contracts: it consists of two cylinders, each covered with an endless web, which are so placed that they form a sort of hopper on their two upper cylindrical surfaces, the ends being enclosed by two iron plates. The tempered clay is thrown into this hopper, and at the lower part it acquires the form and dimensions of a brick. Beneath is worked an endless chain, by the movement of the cylinders, and at various marked intervals are laid the pallet-boards under the hopper; the clay is brought down by a slight pressure, and enters a frame, which has a wire stretched across it, which projects through the mass, and cuts off the requisite thickness; this is immediately removed by the forward motion of the endless chain, and this operation is renewed as often as a new pallet-board is advanced under the hopper. This machine produces about 1,200 bricks per hour, and is worked by two men and three boys. By this plan less pressure is given than in most machines, consequently the bricks are less difficult to dry equally.

Machine-made bricks are smoother, heavier, and stronger than other bricks, but they do not adhere so well to the mortar, and are more difficult to dry well than those made by hand.

BRICK-MAKING MACHINE, ROTARY AND LOCOMOTIVE—By JOSEPH GRANT. Fig. 608 is a plan of the machine.

Fig. 609 is a side elevation, with one of the propelling wheels removed.

Fig. 610 is an end view of the mould-cylinder.

Fig. 611 is a transverse vertical section of the machine, seen from the back, showing the mould-cylinder in longitudinal section.

Fig. 612 is a transverse sectional elevation of the mould and pressing cylinders in part, with hopper attached, appearing as in operation.

608.

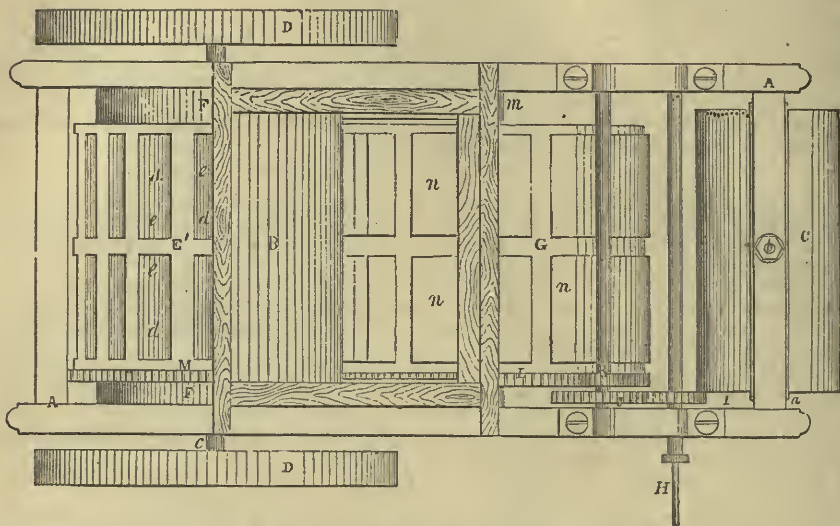
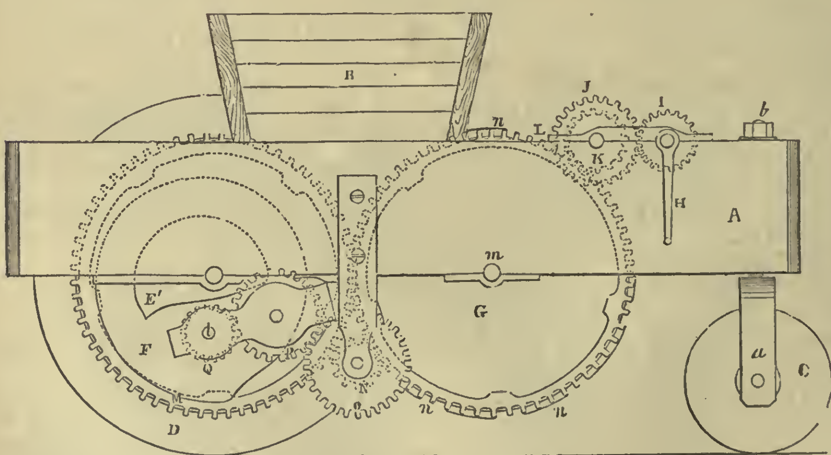


Fig. 613 is a view in detail of a grooved channel and cam, used in working the followers.

The same letters of reference denote similar parts throughout the several figures.

The nature of this invention consists in the use of two cylinders set horizontally in a suitable framing and revolving in opposite directions, being driven by geering, which also propels the machine forward as the brick is being made.

609.



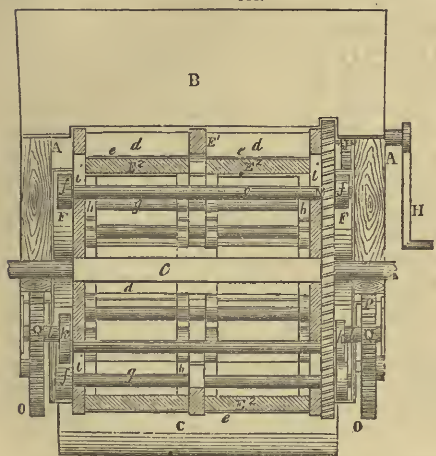
One of these cylinders is fitted with moulds, working in which are followers, forming the bottom of the moulds, and operated by rollers moving in fixed grooved channels, and by cams producing the drop-motion. The second or pressing cylinder is provided with plates working and fitting into the moulds of the other cylinder, pressing the clay, which is fed from a hopper above and between the two cylinders, the clay being drawn into the several moulds by its own weight and the revolving motion of the cylinders, and the bricks deposited on the ground or surface prepared for them, in regular layers or line as the machine moves forwards; a roller in front clears or prepares the ground or surface on which the bricks are to lay. The followers in the moulds are covered with cloth or similar material to prevent the clay or soft bricks from adhering to them—the machine being worked by hand or other power

To enable others skilled in the art to make and use this invention, the inventor describes its construction and operation as follows:

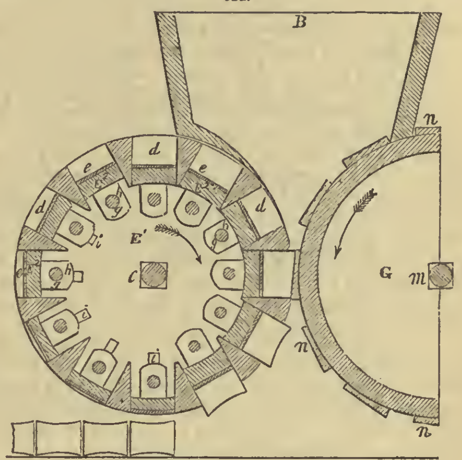
A A is the frame of the machine; B, the hopper through which the clay is fed; C, a levelling-roller, serving to carry the machine, and to clear or prepare the yard for deposit of the bricks; it works in a strap *a*, having a swivel-spindle *b*, to admit of the machine being moved about in any direction.

D D are travelling or propelling wheels fitted on the mould-cylinder shaft *c* and turning with it; E′ is the mould-cylinder keyed fast to the shaft *c*; it is made of iron, or other suitable material, and has on its circumference or surface spaces *d d d* forming the moulds. The number of moulds is not limited to two rows, as shown in the drawing, but will be dependent upon the length of the cylinders as well as the diameter; each mould or space *d d d* being only of the length of the brick, so that the machine may, if required, be constructed to form three or more layers.

611.

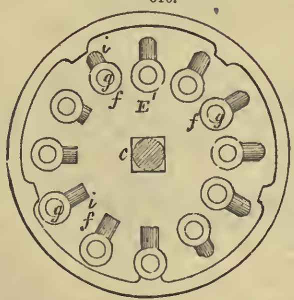


612.

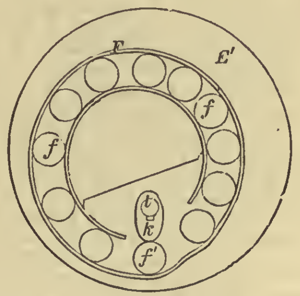


E^2 E^2 E^2 are followers, or plungers, working in and forming the bottom of the mould; they are covered on their top with fine cloth *e e e*, and are of length and breadth so as to fit loose in the moulds *d d d* in which they move, motion being given to them by rollers *f f f*, which turn on spindles *g g g* running through the cylinder E′ lengthways, passing through slots *i i i* at both ends; the spindles *g g g* are connected to the followers E^2 E^2 E^2 by pieces *h h h* attached to them, through which the spindles *g g g* pass, the rollers *f f f*, as the cylinder E′ is caused to revolve, moving in fixed grooved channels F F secured to the framing A A, the interior of one of which is seen in Fig. 3994, being positioned with relation to the cylinder E′ in the manner of an eccentric, one at either end, but differing from an eccentric in their being made of a scroll or irregular curve formation. The rollers *f f f*, travelling in the grooved channels F F, cause the followers E^2 E^2 E^2 to move in the moulds *d d d*, the followers at their bottom stroke leaving a space in the mould equal to or rather exceeding the thickness of a brick, and when forced out, working nearly to the outer edge of the moulds *k k*.

610.



613.



In fig. 613, are represented cams attached to shafts *l l*, and so positioned and set as to form as many revolutions for one revolution of the cylinder E′ as there are moulds in a single row, causing the cams *k k*, one at either end, to strike the rollers *f f f*, two together, that is, one at either end, and so on for all the rollers successively as they assume the position of *f*′, Fig. 613, causing the formed bricks to be shaken from their moulds when arriving at a perpendicular position. The bottom of the mould-cylinder E′ is situated rather more than the thickness of a brick from the ground or yard surface.

G is the pressing cylinder revolving in the opposite direction to the cylinder E′; it is keyed on the shaft *m*. *n n n* are pressing-plates fitted on the circumference or surface of the cylinder G, correspond

ing to the spaces or moulds *d d d* in the cylinder E′, into which they fit or press the clay; they are made thicker at the edge first entering the mould than the finishing or after edge, as shown more particularly in Fig. 612.

H is a handle for giving motion to the machine, (but the arrangement may be such that steam or other power may be applied.) I is a pinion turned by handle H; it operates a wheel J, on the shaft of which is a pinion K working into a wheel L fitted fast to the side of the cylinder G; the wheel L is in geer with a corresponding wheel M attached to the cylinder E′; the wheel L also drives a pinion N, on the shaft of which are wheels O O, one at either end, working into similar wheels P P that drive pinions Q Q fitted on the cam-shafts *l l*, which they operate. The relative proportions of these several wheels and pinions are such as not only to obtain additional power, but to operate the drop-motion formed by the cams *k k* at a proper time—that is, to strike the rollers when they assume the position of *f′*, Fig. 613, so as to release the brick, and likewise to operate the propelling or travelling wheels, which are of a suitable relative diameter, so that the machine will move at a speed proportioned to the discharge of brick, causing the bricks made to be deposited regularly, side by side, in layers.

The operation is as follows: clay being put into the hopper B, the handle H is made to turn, and by wheels and pinions I J K L and M the cylinders E′ G are made to revolve in opposite directions, as shown by arrows in Fig. 612, drawing the clay, partly forced by its own weight, into the moulds *d d d*; the pressing plates *n n n*, entering the moulds at their thick edge first, press, and together with the moulds form the brick; the plates *n n n* leaving the moulds at their thin edge, obviates the tendency which the soft brick has of being pressed thinner at the side or edge, receiving the last or latest impression. While the cylinders E′ G are performing this operation, the machine, through means of the propelling wheels D D, is moving forwards, and the several followers or plungers E^2 E^2 E^2 are being worked by means of the rollers *f f f* travelling in the fixed grooved channels F F, which causes the followers or plungers E^2 E^2 E^2 to draw in for receiving the clay, and when the brick is made to be forced out, and so drive out the brick, which is further released from the mould by the action of the cams *k k*, driven by the geering N O O P P Q Q, the cams *k k* striking the rollers *f f f* when arriving in the position of *f*, Fig. 613, and dropping or shaking the brick from the followers, which, being covered with fine cloth or other similar material, are not so liable to retain or cause the soft brick to adhere. The bricks are laid in the yard side by side and in perfect layers, in the manner shown in Fig 612, the number of layers being dependent upon the size of the machine or length of the cylinders E′ G, which may have one, two, three, or more rows of moulds or pressing-plates. This machine, therefore, not only makes bricks rapidly, but of an equal thickness, sound and perfect; and by being locomotive, can be moved about in any direction as convenience suggests, laying in the yard in regular order the bricks as made.

BRICK-MAKING MACHINE—Whipple's *Improvement, patented March* 25, 1851. Fig. 614 is a diagram illustrating the pulverizing or crushing action of the machine.

Fig. 615 is a side elevation of the machine.

Fig. 616 is a front or end elevation.

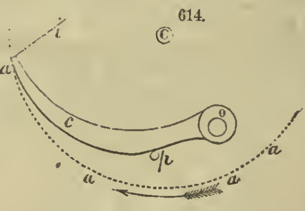
Fig. 617 is a longitudinal section.

Fig. 618 is a transverse section.

The same letters of reference denote similar parts throughout each of the several figures.

The nature of this machine consists in the use of a revolving screen working on a stationary axis set at a slight inclination from a horizontal position, and having attached to, or suspended from it, lugs or crushers, which, by their weight, serve to pulverize the clay; the stock or clay being fed in at one end of the screen, which by its revolving motion carries or drags the stock under the lugs or crushers, thereby breaking and pounding it; the pulverized clay falling through the apertures of the screen, and the waste or hard lumps and stones mixed up with the stock being expelled at the back or lower end of the screen.

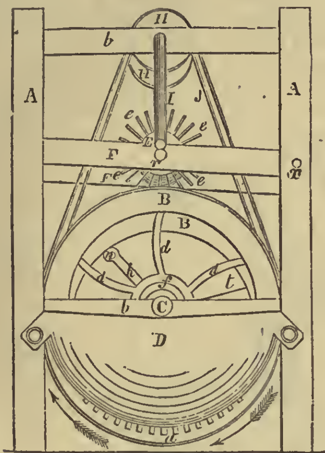
614.



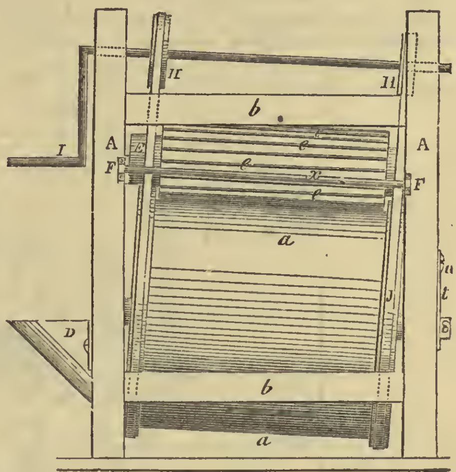
A A are uprights having cross or tie pieces *b b b*, which constitute the framing of the machine, or any similar suitable form of framing may be adopted; *a a a* are the bars forming the screen; they may be placed at any required distance apart, and are bound, or secured, in a cylindrical form, by hoops B B, into notches in which the ends of the bars *a a a* may fit, or be otherwise attached. To the hoops B B are arms *d d d*, connected with naves F F, which form the rotary bearings of the screen; the bars *a a a a* should be of such a shape in their cross section and so arranged as that any particles once entering the spaces, from within, between them, will readily pass off, that is, they should be broader on their interior than their exterior edges, thus making the outside width of the spaces greater than the inside, as is the case with many descriptions of fire-grates now in use; and for which purpose bars of a triangular, or any appropriate shape, may be used, their narrowest or curved face or sides being set outside: or the screen may be made of a cylinder having slots or openings corresponding to spaces formed by the bars *a a a a*. C is the stationary axis on which the naves F F of the screen rotate; it rests on the lower cross-pieces *b b*, and is kept or prevented from turning by its back end *s* being made square, and an arm *t* being fitted into it, the other end of the arm *t* being fastened to one of the uprights A by a screw *u*, Fig. 615, or any other simple and well-known arrangement may be used for keeping the axis C stationary; which is set, as will be seen by reference to the drawings, at a slight inclination from the horizontal position, for the purpose of giving the screen a corresponding position, or a dip at its back end. D is a feed-hopper or trough, which also is stationary. To the axis C are keyed, or otherwise secured, arms *h h l l m m*, seen more particularly in Figs. 617 and 618. *n* is a cross-bar connecting the arms *h h*. O is a bar connecting similar arms *l l*, and *p* a rod connecting the arms *m m*. *c c c c* are lugs or crushers having their fulcrum, or working as a hinge-joint, on the rod O, and at their other extremity

attached by cords or chains *i i i i* to the bar *n*, and resting on at their lower edge, or supported, by the rod *p*: either arrangement of the arms *h h*, cords or chains *i i i i*, or cross-bar *p* and arms *m m*, may be used for supporting or holding the lugs from touching or rubbing the screen; or both arrangements, as shown and described in combination, may be used. The lugs or crushers *c c c c c* may be made of any material, size, shape, and weight. *e e e e* are pickers arranged in a radial form round a small drum E, keyed to an axis *r*, working at either end in side-levers, or pieces F F. The pickers *e e e e* are of nearly the same length as the bars *a a a a* of the screen, and are of proper thickness and width apart to drop into the spaces between the bars *a a a a*. The side-levers F F are hung on a rod *x*, forming a joint on which to work, and their other end connected by a bar G, which is held by a catch or hook *g*, Fig. 618, H H are pulleys, being driven by a handle I, attached to their shaft or axis. The pulleys H H serve to drive the screen by straps J J, which pass round them and the hoops B B.

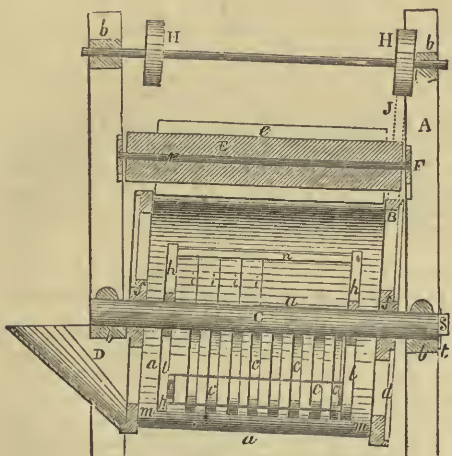
616.



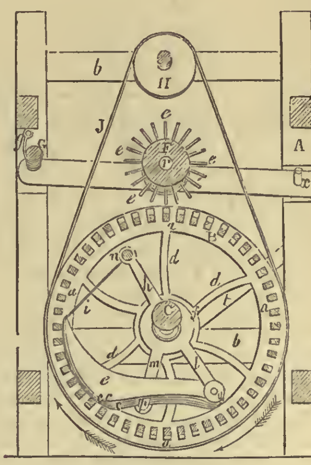
615.



617.



618.



I will now proceed further to describe the operation. The stock, or rough clay, is fed by the hopper D into the screen formed of bars *a a a a*, entering under the lugs *c c c c c*, and by the revolving motion of the screen in the direction shown by the arrows, Figs. 614, 616, and 618, the stock is carried under the lugs *c c c c c*, which yield or give, working on their joint *o*, and so produce a pressure by their weight on the clay, which serves to clear the stock, the fine and workable portion being pulverized and passing through the spaces between the bars *a a a a*, and the waste or hard lumps and stones mixed up in the stock, being worked out of the back end of the screen, the inclination of which downwards, and the revolving motion of the screen serving to expel the same. The object of the rod *p*, or cords *i i i i*, is to prevent the lugs from rubbing the screen, which would create unnecessary friction. The several lugs or crushers may be made of different sizes, shapes, or weights; those at the mouth of the screen, if desirable, made so as to merely break the stock, and the after-crushers

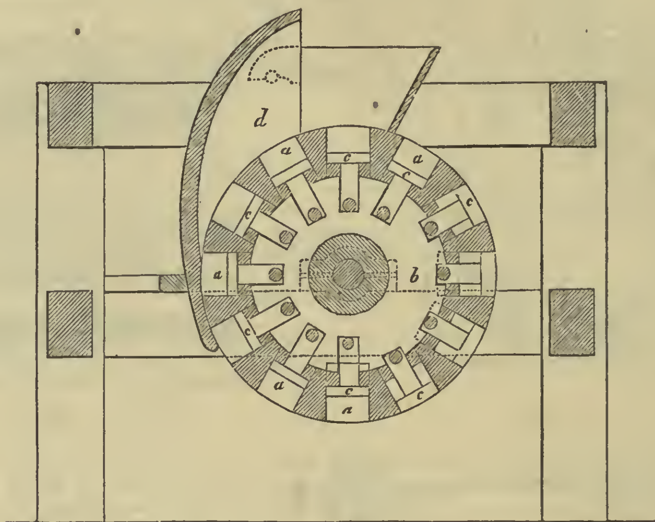
or lugs to pulverize the finer clay which is collected under the screen formed by the bars *a a a a*, and is thus tempered or prepared for making bricks.

The pickers *e e e e* may be thrown in or out of geer with the bars *a a a a*, by lowering or raising the side-levers F F, working as a hinge-joint on the rod *x*. By unfastening the hook *g*, Fig. 3999, the pickers *e e e e* are thrown in geer, entering the spaces of the bars *a a a a*, which, as the screen rotates, drives or causes to rotate also the pickers *e e e e*, which pick out or clear the screen of any soft clay or dirt which may clog the spaces between the bars *a a a a*. By the hook *g* the picker is thrown in or out of geer, and used only as required.

BRICK PRESS. *Patented by* John Riddle, Covington, Ky., April, 1851. In order to the formation by simple pressure, from untempered clay, of bricks possessing the requisite unity and coherency of structure, it is absolutely essential that the pressure should be uniform throughout their entire mass.

This result has never, to our knowledge, been attained, except by the application of pistons on opposite sides of the brick; but this mode, although (while the machinery remains in working order) adequate to the formation of a good article, is particularly ineligible, on account of its liability to clog and become deranged. The fact is, a brick-machine should have as few working joints as possible, especially in those parts which are in immediate connection with the clay.

619.



Machines in which the bricks are formed either in the circumference of a large wheel or in a straight bed of moulds, in connection with a wheel, by a simple rolling motion, have the requisite simplicity, but the pressure not being applied to all parts of the clay at once, the mass, while being pressed down at one part, rises up at other parts, which have passed the point of pressure, and cracks and becomes unequal in consistence; and having once taken its set, no pressure afterwards is adequate to rectify the defect. These difficulties the inventor has entirely overcome by a working machine containing the following devices, to wit:

Fig. 619 is a longitudinal section through the mould-wheel and its appurtenances.

The moulds *a* are placed around the perimeter of a wheel *b*, and the pressed brick may be extruded by followers *e*, which may fall back against a solid shoulder in the wheel, as usual.

The distinguishing features, however, of this arrangement exist in the peculiar construction of the feed-trough *d*, and its appendages; the trough is made to gradually narrow downwards, until it comes closely in contact with the rim of the wheel, and is thence extended forward in the form of a lip or flange *o*, hugging closely the wheel, and made to bear hard up against it, so that the clay, after its introduction into the trough, is squeezed into a smaller and smaller compass, as it descends, and by this means is pressed forcibly into the mould, until, coming in contact with the lip, the entire mass receives its ultimate compression powerfully and equally applied in every part.

BRIDGES. Bridges are constructed of various materials, arranged in varied forms. Bridges of stone or brick are arched; of wrought iron, tubular and trussed; of cast iron, plain girders; of wood, trussed. Cast and wrought iron are often used together; wood and wrought iron, in trussed and suspension bridges.

The forms of arches are varied—the semicircular, the segmental, and the elliptic. The most common form in use in this country is the segmental (fig. 621), the arc subtended being about 45°. Without going into the theory of the arch, requiring considerable mathematical knowledge, we proceed to give certain rules from the best authors, and examples of construction, to enable the mechanic to proportion the parts of a structure.

That the voussoirs of an arch may resist crushing, they must have a certain depth proportioned to the pressure of the arch; and as this increases from the curve towards the springing, the depth of the voussoirs should likewise increase from the crown to the springing. Peronnet has given as a rule for

the depth at the crown the formula $d =$,07 $r + 1$ foot, in which formula r is the greatest radius of curvature of the intrados. This formula is applicable to arches less than fifty feet radius; but beyond this it gives greater dimensions than in ordinary practice. In order to facilitate investigations on the stability of arches of the more usual forms, M. Petit calculated a series of tables, of which we give the abstract for circular arches, as the class occurring most frequently in practice.

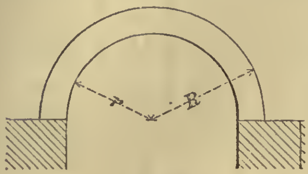


Fig. 620.

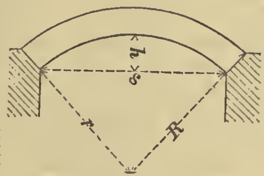


Fig. 621.

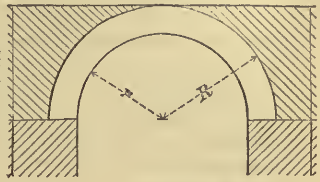


Fig. 622.

To find the thickness of abutment necessary to support the thrust of the arch, multiply the co-efficient found in the table for the particular case by 3.8, and the square root of the product multiplied by the radius, r, of the intrados, will give the extreme thickness of the abutment.

CO-EFFICIENT OF HORIZONTAL THRUST AT THE CROWN.								
Ratio of the Radii $\frac{R}{r}$	Fig. 620.	Fig. 622.	Fig. 621.					
			$s = 4h$, $\frac{r}{h} = 2.5$	$s = 5h$, $\frac{r}{h} = 3, 265$	$s = 6h$, $\frac{r}{h} = 5$	$s = 6h$, $\frac{r}{h} = 8.5$	$s = 10h$, $\frac{r}{h} = 13$	$s = 16h$, $\frac{r}{h} = 32.5$
1.50	0.191	0.217						
1.45	0.168	0.192						
1.40	0.162	0.169	0.154	0.147	0.147	0.147	0.045	
1.35	0.153	0.147	0.148	0.130	0.126	0.126	0.124	
1.30	0.143	0.143	0.137	0.123	0.106	0.106	0.104	
1.25	0.128	0.139	0.126	0.114	0.100	0.086	0.084	0.072
1.20	0.111	0.131	0.110	0.102	0.091	0.070	0.066	0.056
1.15	0.092	0.119	0.091	0.086	0.079	0.063	0.049	0.041
1.10	0.068	0.103	0.067	0.065	0.062	0.052	0.042	0.027
1.05	0.038	0.082	0.038	0.038	0.037	0.034	0.029	0.019

Example.—What is the horizontal thrust, and what the thickness of abutment necessary to support an arch of ten feet span and two feet rise?

$$\frac{s}{h} = \frac{10}{2}, \text{ therefore } s = 5h.$$

$$\frac{r}{h} = \frac{r}{2} = 3.625 \qquad r = 3.625 \times 2 = 7.25 \text{ ft.}$$

By Peronnet's formula, $d = 0.07 \times 7.25 + 1 = 1.50$.

$$R = 7.25 + 1.50 = 8.75$$

$$\frac{R}{r} = \frac{8.75}{7.25} = 1.20$$

By the table against 1.20, under the column $s = 5\ h$, we find 0.102 as the co-efficient of thrust, 150 lbs. being taken as the average weight of a cubic foot of masonry, the absolute thrust per square foot of surface is

$$0.102 \times 150 \times \overline{7.25}^2 = 804 \text{ lbs.}$$

$$\sqrt{0.102 \times 3.8} \times 7.25 = 4.50 \text{ feet, thickness of abutment.}$$

The formula gives the thickness of abutment, supposing the height infinite; for low abutments, the thickness may be reduced, for common spans, about ten per cent.

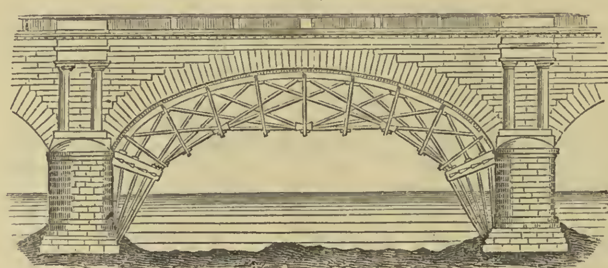
In the loading of a semicircular arch, especially, the tendency of a weight applied at the crown, is to rise the haunches. This is to be counteracted by backing with masonry at these points called the spandrel backing. When the arch is to be covered with earth, care should be taken in loading the arch evenly at both sides. The same remark applies to the setting of the arch-stones on the wooden centres whilst in process of construction.

The following table gives the dimensions of the arches of a selection of bridges of European construction.

LOCATION.	Material.	Form of Arch.	Span.	Rise.	Depth at crown.	Depth at spring.
			ft. in.	ft. in.	ft. in.	ft. in.
Manchester and Birmingham Railroad,	Brick,	Semicircular,	18	9	1 6	uniform.
" " "	"	"	63	31 6	3	"
London and Brighton "	"	"	30	15	1 6	2 3
" Blackwall "	"	Segmental,	87	16	4 1½	uniform.
Great Western "	"	Elliptical,	128	24 3	5	7 1½
Orleans and Tours "	Stone,	Semicircular,	27 7		2 7½	uniform.
Stirling Bridge, ...	"	Segmental,	60	13 6½	3 6	4 6
Carlisle "	"	Elliptical,	65	21	3 9	7 4
Staines "	"	Segmental,	74	9 3	2 4	5 6
Hutcheson "	"	"	79	13 6	3 6	4 6
Jena "	"	"	71 9	10 9	5	

For smaller culverts of 15 to 30 feet span, the usual construction is to make the arch from 1 foot 6 inches to 2 feet deep. Arches in stone are seldom turned less than 1 foot deep, whatever may be the span; brick arches for less than 10 feet span are generally 8 inches, and this depth is required by building acts.

623.

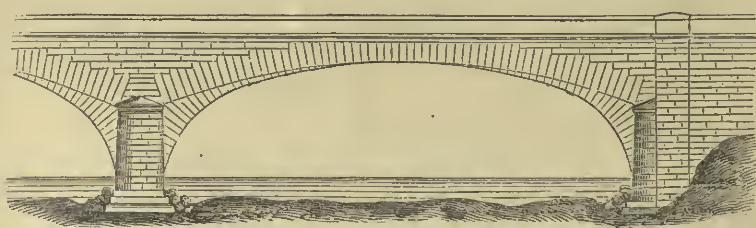


Details of one of the arches and centreing of Waterloo Bridge.

Waterloo Bridge, London, by Rennie, is considered a masterpiece. It was commenced in 1810, it is a level bridge, having nine arches, each 120 feet span, and 35 feet rise, and it is 42 feet 4 inches wide between the parapets.

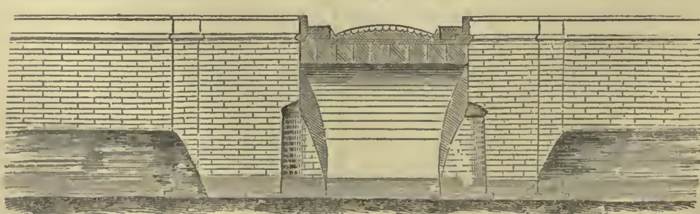
The bridge across the Seine, at Neuilly, built between the years 1768 and 1780, by Péronett, is a

624.



Elevation of one of the arches of Neuilly Bridge.

625.

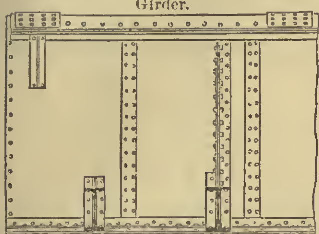


Transverse section of Neuilly Bridge.

very celebrated structure; it is also a level bridge, consisting of five elliptic arches, each of 128 feet span, and 32 feet rise.

Iron bridges.—The most popular form of wrought iron bridges in England is the tubular, applied on a large scale, the travel being in the interior, as at the Conway and Menai Bridge. See CONWAY TUBULAR BRIDGE. Or girders being constructed on this principle, over which the travel passes. See STRENGTH OF MATERIALS. The first bridge of this latter class, in this country at least, was built in 1846-7, on the Baltimore and Susquehanna Railroad, by James Milholland. Figs. 626, 627, 628, 629, represent still another form of plate-iron bridge, as designed by Mr. Martin, the engineer, to carry the railway from the London and North-Western Railway to the East and West India Docks. It carries the railway over Randolph street, Camden Town.

Fig. 626.—Side View of Longitudinal Girder.



The peculiarity consists in constructing the bridge with two side girders, each of a single web, of plates of iron, 71 feet long, 6 ft. 7½ inches high, and $\frac{5}{16}$ inches thick; put together with plates 5 inches wide, overlapping the vertical joints, and ¾-inch rivets placed 3 inches apart, and fixed to the top and bottom plates by angle-iron 3 inches wide, and ¾-inch rivets. The bottom plate is 2 ft. 8 in. wide, made with $\frac{5}{16}$-inch plates in lengths of 8 feet each, with plates overlapping the joints 6 in. wide. The outer flange is curved down 1 inch, to throw off the wet; the top plate is 2 ft. 8 in. girt, made with $\frac{5}{16}$-inch plates, excepting the three middle plates, which are ⅜-inch in thickness; the top is curved down 5 inches, and put together with inch rivets. The girders are stiffened by eight vertical plates on each side of the web, of $\frac{4}{16}$-inch iron, fixed by angle-iron 3 inches wide, and ¾-inch rivets placed 4 inches apart. There are also two similar stiffeners at each end, of ⅜-inch iron. The top plate is further stiffened by stays of T-iron, 5½ inches wide between each pair of stiffeners.

Fig. 627.—Enlarged Section of Girder, showing the Stiffeners,

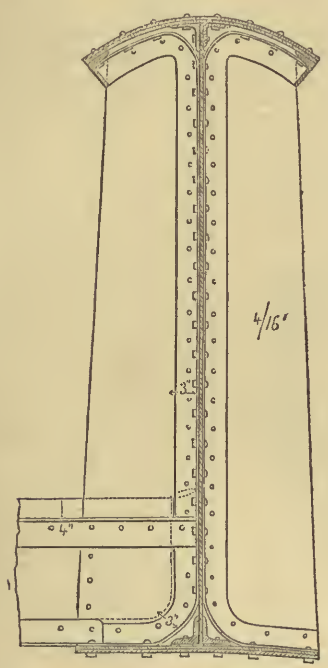
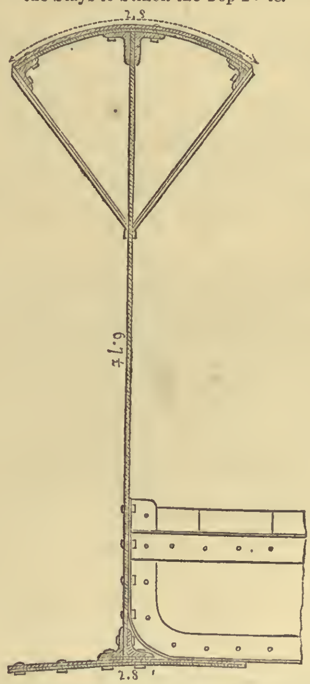


Fig. 628.—Section through Girder, showing the Stays to Stiffen the Top Plate.



The cross girders are 24 ft. 6 in. long and 1 ft. 4 in. high, made with ⅜-inch plates in three lengths, and stiffened by angle-iron top and bottom, and on each side, 3½ inches wide, and fastened with ¾-inch rivets 4 inches apart. The ends of these cross girders rest upon the two girders first described.

Fig. 629.—Transverse Section.

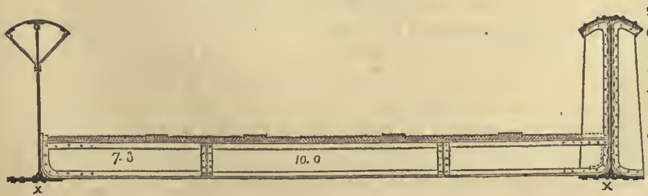
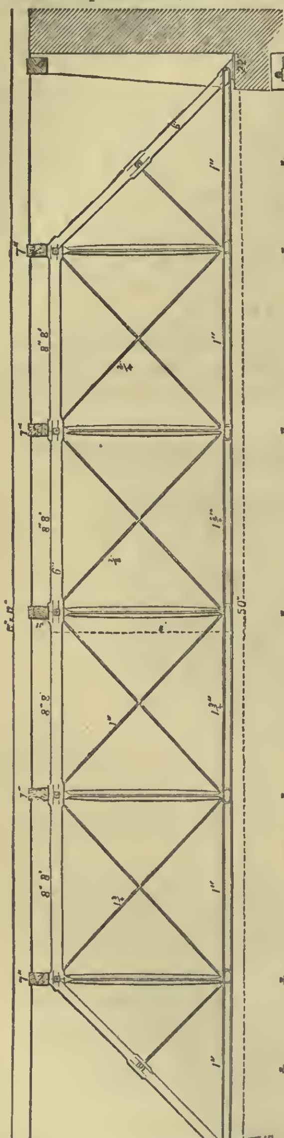


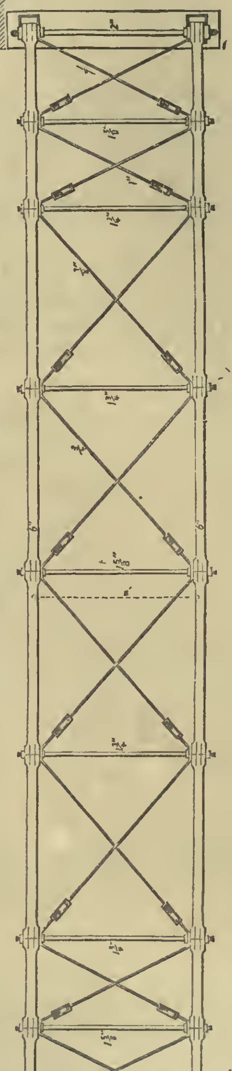
Fig. 629 is a cross section of the bridge. Fig. 626 is a side view of part of one of the longitudinal girders. Fig. 627 is an enlarged section of one of the girders, showing the stiffeners. Fig 628 is a section through the same girder, showing the tays to stiffen the top plate.

Cast-iron bridges.—Bridges constructed of this material alone are usually of short span and simple girders. See STRENGTH OF MATERIALS. Cast iron as a material is not considered as safe as wrought iron or wood; from some flaw, from frost, or from sudden jars, it gives way without notice; but as it is stronger per square inch than wrought iron in resisting a crushing force, it has been applied in connection with wrought iron where the strain is of this description. Whipple's bridge, figs. 630, 1, 2, 3, 4, is a bridge of this description.

630.



631.



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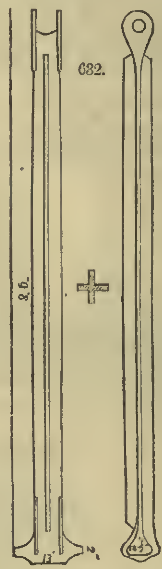
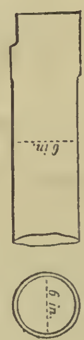


633.



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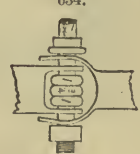
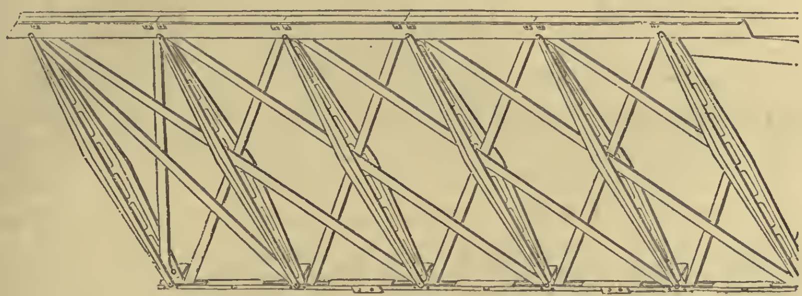


Fig. 630 represents the elevation, fig. 631 the plan, and figs. 632, 3 and 4, the details of framing. This bridge consists of two iron trusses of 50 feet span, and 9 feet high. What would be called the upper chord consists of cast-iron pipe, 6 inches in diameter, and $\frac{1}{2}$ inch thick, equal to 9 square inches—cast-iron uprights of + section, and 8 feet 4 inches apart from centre to centre, connect the upper chord on which the track rests, with the bottom or tie. This latter is of $1\frac{1}{4}$ round iron, in loops, two of which, side by side, constitute the tie between each pair of uprights. These loops pass over shoulders at the foot of the uprights, through which shoulders pass the diagonal $1\frac{1}{4}$ inch wrought-iron rods, secured and adjustable by nuts. The dimensions of all parts of this bridge are proportioned to the strains they are to receive, and were calculated to withstand a rolling weight of 2,000 lbs. per running foot.

The weight of one truss with its proportion of track is less than three tons, or 6,720 lbs.. which is equivalent in its strain to 3,360 lbs. placed on the centre of each truss, to which add the weight at the centre to a load of 2,000 lbs. per foot run, viz., 25,000 lbs., and we have, as the weight on the centre of each truss, 28,360 lbs.

The Rider iron bridge, of which fig. 635 is an isometrical view of the method of framing, is also a combination of wrought and cast-iron in the form of a truss, but it is deficient in strength. The upper chord is of cast-iron, in two parts, bolted together, and "breaking joint," and forming a T section of about 12 square inches. The lower chord is of wrought-iron, composed of two plates, each 4 inches deep, by $\frac{1}{2}$ inch thick, placed side by side, with an interval of $\frac{5}{8}$ inch between them to receive the diagonal rods. These plates also "break joint," and at the joints have an additional plate of the same depth and thickness, and nearly two feet in length; the whole secured together by four bolts, two on

635.



each side of the joints. The uprights or posts connecting the chords, and to which they are bolted, are of cast-iron, about 3 feet 4 inches apart, of an H section, and of 8 square inches in area. Through a hole in the centre of these pass the diagonal rods, two in each pannel, of wrought-iron 2 by $\frac{5}{8}$ inches in the centre, and $2\frac{1}{4}$ by $5\frac{5}{8}$ inches at the ends; these are also bolted to the top and bottom chord.

Bollman's Bridge is still another combination of the same sort, but differs from the others in that there is no bottom chord necessary. The top chord and posts are of cast-iron, and the bottom of each post is supported by rods to either end of the upper chord. It may be considered a trussed cast-iron beam. The principles of the construction will be readily understood from the description. The largest of these bridges is at Harper's Ferry, and they are used considerably on the line of the Baltimore and Ohio Rail Road.

636.

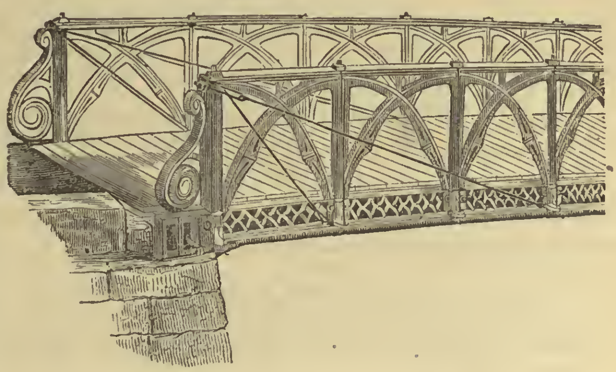
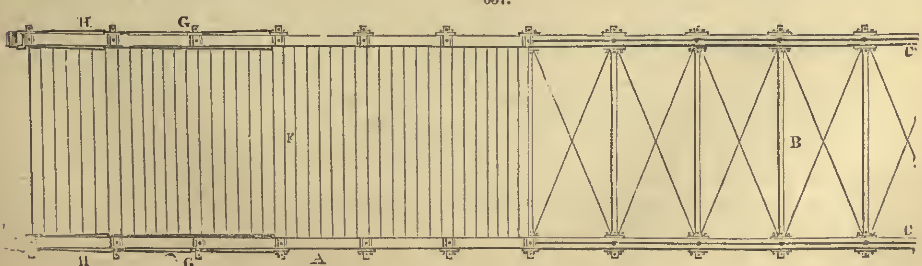


Fig. 636, is a perspective view of a part of Severson's Iron Bridge, near the abutment; it is cambered about 1 in 80 or 100—the whole combined forming a trussed girder. The sides or body of the truss, when made of cast-iron, will be composed of pieces, or voussoirs, corresponding in all parts with the arc of a circle, having a verse sine of 1 to a chord of 80 or 100. The ends and joints between the voussoirs being radii, the main ties made of wire cables, and the lower and upper parts of the voussoirs, will form three concentric arcs.

In fig. 637, at F is represented a portion of the floor as

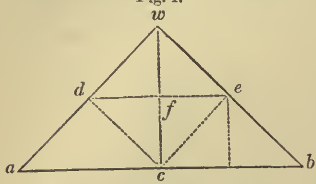
637.



seen from above; A, the upper rail, or arc; G G and H H the quarter braces; E, end pieces. At B is half the bridge as seen from below; D D, bottom of end pieces; C C, main cables, or ties. The sway-braces and under side of girders between C C at B.

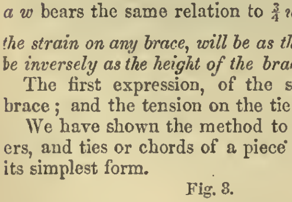
Wooden Bridges.—The simplest form of bridges is of course composed of single beams or string-pieces spanning the opening, on which are laid the floor-planks. For the strength of such beams, see STRENGTH OF MATERIALS. But as such constructions are only applicable to small spans, framed structures become necessary. We proceed therefore to investigate the general principles of trussing, applicable as well to iron as wooden constructions.

Fig. 1.



Commencing with the simple truss, let $a\ w$, $b\ w$ be two equal braces connected at the foot by the tie $a\ b$, and neglecting its own weight for the present, suppose the truss to sustain a weight W at the point w. Draw $w\ c$ perpendicularly to the tie, and let it represent in magnitude the weight W, that is to say, so many pounds as there are in W; let there be inches or half-inches or any convenient unit of measure in $w\ c$. Draw $c\ d$, $c\ e$, respectively parallel to $w\ b$ and $a\ w$; now by the composition and resolution of forces, $w\ e$, measured by the same scale as $w\ c$, will represent the thrust in the direction of $w\ b$, caused by the weight $w\ c$ or W; and $w\ d$ likewise equals in direction and magnitude the strain or thrust in the direction of the brace $a\ w$. We suppose the framing to rest at the points a and b on immovable supports; of course, half the weight, $\frac{1}{2}$W, will bear on each support, a and b; and the action at these points will be compounded of a vertical pressure equal to $\frac{1}{2}$W, and a horizontal strain or tension in the direction $a\ b$, equivalent to $\frac{1}{2}\ \mathrm{W}\ \frac{a\ c}{w\ c}$ For drawing $d\ e$, parallel to $a\ b$, bisecting in $f\ d\ f$ represents the tension on the tie $a\ b$. For *when three forces are in equilibrio about a point, if two of them are represented in direction and magnitude by the two sides of a triangle, the third side of this triangle must represent in direction and magnitude the third force.* Now, the point a is acted upon by three forces: an upward resistance equivalent to $\frac{1}{2}$ W, a pressure in the direction $w\ a$ equal to $d\ w$, and the tension of the tie $a\ b$ which will be the third side of the triangle of which the other two are $d\ w$ and $f\ w$, that is, $d\ f$; and in the similar triangles $w\ d\ f$, $w\ a\ c$, $d\ w : f\ w :: a\ w : c\ w$; and $d\ f : f\ w :: a\ c : c\ w$; or the strain in the direction of $a\ w$ bears the same relation to $\frac{1}{2}$ W that $a\ w$ bears to $c\ w$, and the tension on the tie bears the same relation to $\frac{1}{2}$ W that $a\ c$ bears to $c\ w$, or tension $= \frac{1}{2}\mathrm{W}\ \frac{a\ c}{c\ w}$ On the supposition that the braces are of different lengths, or the weight not immediately over the centre of the tie $a\ b$, we should still have the respective strains determined in the same manner. Thus $w\ c$ representing the weight w, sustained by the braces $a\ w$ and $b\ w$. Completing the parallelogram on this as a diagonal with the direction of the forces for the sides, and drawing $d\ f$ parallel to the tie $a\ b$, we have as the result of this arrangement an inequality in the action of the weight on the points a and b. $w\ f$ represents the weight on the point a, and $f\ c$ represents the weight on the point b; and the side of the triangle $w\ d\ f$, as in the first case, represents all the forces in operation on the point a—viz.: $w\ f$ (the weight on a) which bears the same relation to $w\ c$ (or the whole weight) that $c\ b$ bears to the whole tie $a\ b$. $d\ w$, the strain on the brace $a\ w$, and $d\ f$, the horizontal tension in the direction of the tie $a\ b$.

Fig. 2.

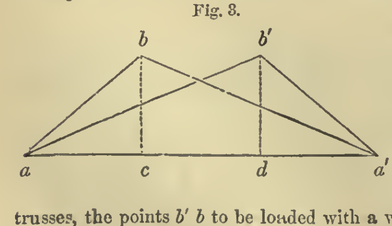


To determine these strains in terms of the given dimensions, as in the first example, we have (taking for convenience of calculation $a\ c$ as some multiple of $a\ b$, say $\frac{1}{4}$) by similar triangles, $d\ w : f\ w : a\ w : c\ w$, and $d\ f : f\ w :: a\ c : c\ w$; or the strain in the direction of $a\ w$ bears the same relation to $\frac{3}{4}\ w$ that $a\ w$ bears to $c\ w$; or $d\ w = \frac{3}{4}\ \mathrm{W}\ \frac{a\ w}{c\ w}$ and $d\ f = \frac{3}{4}\ \mathrm{W}\ \frac{a\ c}{c\ w}$ or *the strain on any brace, will be as the length of the brace, divided by its height, and the tensions on the tie will be inversely as the height of the braces.*

The first expression, of the strain on the brace, is the cosecant of the angle of inclination of the brace; and the tension on the tie is the cotangent of the same angle.

We have shown the method to be pursued in calculating the strains on the respective braces or rafters, and ties or chords of a piece of framing, which may be either a truss for a roof, or for a bridge in its simplest form.

Fig. 3.



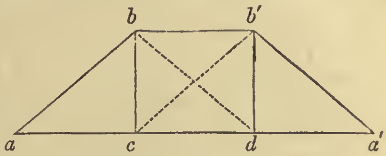
For short spans of either roof or bridge, say from thirty to forty feet, either of the two following forms may be used: The simplest is that shown in fig. , the truss resting on the points $a\ a'$, and the roadway bearing on those points, and on cross bearers at the points c and d. This form of truss is, however, less economical than that of fig. , and less rigid.

For the purpose of comparison, take $a\ a'$, in figs. , divided into three equal parts at the points c and d, and suppose, with the same height $b\ c$ to the two trusses, the points $b'\ b$ to be loaded with a weight, w.

Now it is clear that the weight on the points a and a' is the same in each truss, but the tension on

the tie is in the case of fig. 4, at a, $\frac{a\,c}{b\,c}$ w; but the tension on the tie of fig. 3 is, as before shown, $\frac{2\,a\,c}{3\,b\,c}\,\mathrm{w} + \frac{1\,a\,d}{3\,b'\,d}\,\mathrm{w}$. Substituting in this expression the value of $a\,d$, which $= 2\,a\,c$, and of $b'\,d$, which $= b\,c$, we have the tension $= \frac{4\,a\,c}{3\,b\,c}$ w, which is $\frac{1}{3}$ greater than in the case of fig. 4, of course requiring $\frac{1}{3}$ more material; which excess is not offsetted by the additional material required in the braces $b\,d$, $b'\,c$, of fig. 4, which is the preferable form, unless the abutments sustain the thrust; for in the latter case in fig. 4, the braces $b'\,c$, $b\,d$ cannot act directly on the abutments, as they may do in the case of fig. 3.

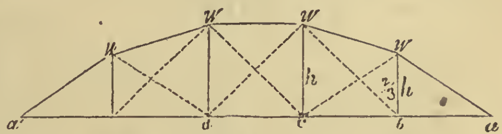
4.



Extending our investigation to longer spans, of say from 40 to 80 feet, the number of bearing points for the distribution of the weight being increased in the proportion of the length, a comparison analogous to the preceding, will show the most economical arrangement for the timber of such a bridge. The independent brace for each point of support, throwing their weight directly on the abutments, is found not to be so economical as the introduction of a straining piece between the heads of the verticals.

Taking the two trusses fig. 5 and 6, of the same span and rise, and divided into five equal spaces, giving four points of support for the load, which we will suppose to be distributed equally at the several points.

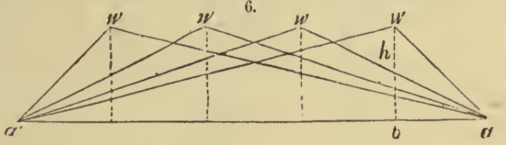
5.



In truss fig. 5, let $a\,a' = 5$ and $a\,b$, $b\,c$ each $= 1$. Let $w\,c = h$ and $w\,b = \frac{2}{3}\,h$. The points $a\,w\,w\,w\,w\,a'$ may be considered as points in a circular arch, and in equilibrio under the weights $w\,w\,w\,w$.

The horizontal thrust on the tie, produced by the weights $w\,w$ &c., is $= \frac{3\,w}{h}$.

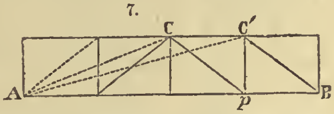
6.



For, as already shown, the action of tension in this case will be represented by $\frac{a\,b}{\frac{2}{3}\,h}\,\mathrm{w} + \frac{a\,b}{\frac{2}{3}\,h}\,\mathrm{w} = \frac{3\,w}{\frac{2}{3}\,h} = \frac{3\,w}{h}$.

In the case of the independent braces, fig. 6 being an equal space and rise, $a\,a$ and h, and loaded with the same weight at the point, $w\,w$, &c. Each pair of braces will exert a certain thrust, and the tension on the tie will be expressed by the sum of the several thrusts produced by all the weights, or $\frac{4}{5}\,\frac{w}{h} + \frac{3}{5}\,\frac{2\,w}{h} + \frac{2}{5}\,\frac{3\,w}{h} + \frac{1}{5}\,\frac{4\,w}{h} = \frac{4\,w}{h}$ is the tension on the tie, which is $\frac{1}{3}$ greater than in fig. 5, hence this latter form of truss would require more timber than that of fig. 5, to bear the same load; and attended with the inconvenience of the long braces, which would not bear the thrust communicated to them as advantageously, as the shorter pieces in fig. 5, but on the other hand the condition of equilibrium may be disregarded, as the weight may be removed from any of the braces without destroying the stability of the structure, whereas in fig. 6, to remove the weight from either of the points w, would destroy the equilibrium, and the truss would yield at once; to prevent this a system of bracing is introduced between the verticals (on the dotted lines), making the whole amount of timber about the same, probably, as in fig. 6, yet the truss with diagonal braces between the verticals, is preferable to that in which independent pairs of braces sustain the points at which the weight is applied, although the latter, as before remarked, is less liable to change of shape by a variable load; the practical inconveniences attending the construction of this form of truss, however, render it every way inferior to the other for long spans.

7.



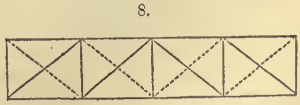
This form of diagonal bracing is the key to almost all our bridge constructions; we therefore extract from Haupt the principles of bracing and counter-bracing.

If the truss, fig. 7, be loaded at c', the effect of the oblique force $c'\,a$ upon the angle c, evidently, is to force it upwards, and this would be the diagonal of a parallelogram constructed upon $a\,c$ and $c\,c'$.

This result is of the greatest practical importance, and the existence of a force acting upwards appears to have been overlooked by many practical builders, as in some very important structures no means have been used to guard against its effects.

The consequence is, that in a straight as well as in an arched truss, a weight at one side produces a tendency to rise at the other side.

8.



The effect of this upward force is to compress the diagonals in the direction of the dotted lines, and extend them in the direction of the braces; but as the braces, from the manner in which they are usually connected with the frame, are not capable of opposing any force of extension, it follows that the only resistance is that which is due to the weight and inertia of a part of the structure. When the load is uniform this is sufficient, because the weight on one side is balanced by an equal weight upon the other, and every part is in equilibrium. But when the bridge

is subjected to the action of a heavy weight, as a locomotive engine or a loaded car rapidly passing over it, and acting with impulsive energy upon every part at different instants, it is obvious that no adequate resistance is offered by a truss composed of only the three series of timbers already described. Yet we find that such a truss has been used for a large proportion of the bridges that have been erected, sometimes with, and sometimes without the addition of an arch, an appendage which, although it adds to the vertical strength, diminishes but little the effect of the force under consideration. No one who has had an opportunity of observing it, can have failed to notice the great vibration produced in such bridges by the passage of a loaded vehicle. In long bridges, the undulations produced by the passage of a car can be felt at the distance of several spans.

The remedy for this defect is obvious; it is only necessary to prevent the diagonal, in the direction of the dotted line, from shortening, or in the direction of the brace from lengthening, and the upward force will be effectually resisted.

This requires either that counter-braces should be introduced in the direction of the dotted diagonals of the last figure, or that the braces themselves should be capable of acting as ties, or additional ties placed in the direction of the braces.

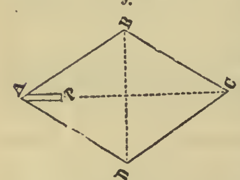
It follows, from the preceding exhibition of the effect of a variable load, that no bridge, either straight or arched, which is designed for the passage of vehicles, and particularly of railroad trains, should be constructed without counter-bracing or diagonal ties. It is only in aqueducts, when the load is always uniform, that they can with any propriety be omitted.

Effects of counter-bracing.—The consideration of the action of counter-braces leads to some very singular but important results.

Let the truss be loaded with a weight so as to produce some deflection, it has been shown that the diagonals in the direction of the braces will be compressed, and in the direction of the counter-braces extended. Suppose that the extension of the last named diagonals is sufficient to leave an appreciable interval between the end of the counter-brace and the joint against which it abuts, and that into this interval a key, or wedge of hard wood or iron, is tightly introduced; it is evident that, upon the removal of the weight, the truss, by virtue of its elasticity, would tend to regain its original position; but this it cannot do, in consequence of the wedges at the ends of the counter-braces, which prevent the dotted diagonals from recovering their original length, and the truss is therefore forcibly held in the position in which the weight left it; the reaction of the counter-braces producing the same effect that was produced by the weight, and continuing the same strain upon the ties and braces.

The singular consequence necessarily results from this, that the passage of a load produces no additional strain upon any of the timbers, but actually leaves some of them without any strain at all.

9.



To render the truth of this assertion more clear, we will confine ourselves to the consideration of a single rectangle, and suppose that the effect of the flexure caused by an applied weight has been to extend the diagonal A C by a length equal A p, and to compress the brace B D by an equal amount.

The point p will evidently be drawn away from A, leaving the interval A p. If a wedge be tightly fitted into this interval, without being forcibly driven, it evidently can have no action upon the frame so long as the weight continues; but upon the removal of the weight it becomes forcibly compressed, in consequence of the effort of the truss, by virtue of its elasticity, to return to its former position. This effort is resisted by the reaction of the wedge, which causes a strain upon the counter-brace A C sufficient to counteract the elasticity of the truss; and as no change of figure can take place, it follows that the brace B D cannot recover its original length, and therefore continues as much compressed as it was by the action of the weight.

The effect of a weight equal to that first applied will be to relieve the counter-brace A C, without adding in the slightest degree to the strain upon B D.

As regards the effects upon the chords, it is evident that the strains are only partial, and tend to counteract each other. The maximum strain in the centre is estimated by the force which would be required to hold the half truss in equilibrium if the other half be removed; and this is dependent only on the weight and dimensions of the truss. In fact, if we examine the parallelogram A B C D, we find that the effect of wedging the diagonals will be to produce strains acting in opposite directions at A and B, and destroying each other's effects; the strains produced by wedging any rectangle cannot therefore be continued to the next, and of course can have no influence upon the maximum forces at the centre.

As the vibration of a bridge is caused principally by the effort to recover its original figure after the compression produced by a passing load, it follows that if this effort is resisted, the vibration must be greatly diminished, or almost entirely destroyed.

This accounts for the surprising stiffness which is found to result from a well-arranged system of counter-braces.

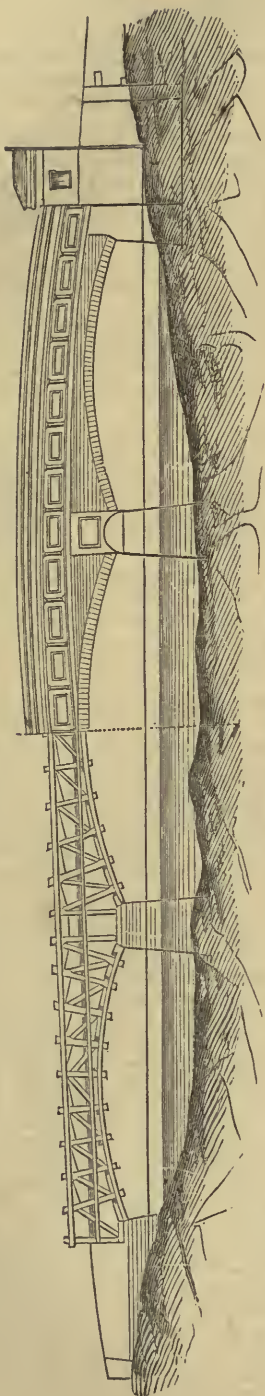
Inclination of braces.—1. The braces must not be so long as to yield by lateral flexure.

2. The chords being unsupported in the intervals between the ties, these intervals must be limited by the condition that no injurious flexure shall be produced by the passage of a load. On the other hand, as the ties approach each other, the angle of the brace increases, and when the intervals become small, the number of ties and braces is greatly increased, and with them the weight of the structure.

The true limit of the intervals can be readily determined when the size of the chords and the maximum load are known; for it should evidently be such that when the load is at the middle, the flexure should not exceed a given amount.

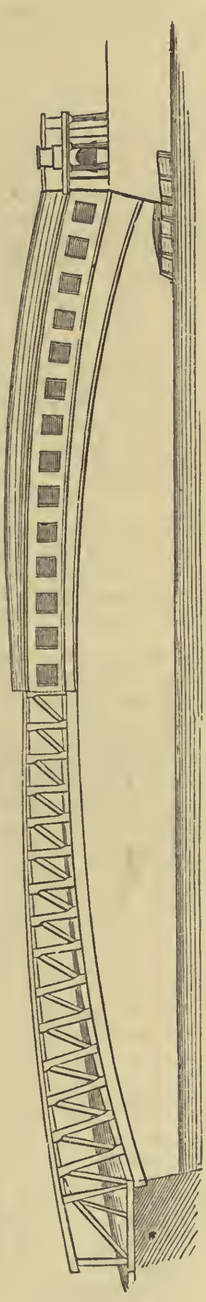
Figs. 638 and 639 represent bridges of which the braces, posts and chords are entirely of wood, but in more common forms wrought iron is used for such parts as are subjected to tension.

638.



Elevation of Schuylkill Bridge. Longitudinal Section.

639.



Elevation of the Upper Schuylkill Bridge. Longitudinal Section.

The most popular form of bridge in use in this country is Howe's truss, similar in form to fig. 8, the bottom and top chords being composed of timber in several thicknesses, the main braces being double, and the counter-braces single, the tension rod or post being of iron. The braces abut on an angular block either of wood or iron, and the tension rods pass through the centre of the block.

In Pratt's bridge the posts are wood, and suspension rods supply the place of braces.

The peculiarity of McCallum's bridge, is in the arrangement through which the arched upper chord by means of the arch-braces bearing on the abutment, together with the counter-brace tension-rods acting on the lower chord, conduce to a uniformity of action highly advantageous to the durability of the bridge.

Suspension Bridges.—Various opinions have been entertained as to the form best adapted for the objects of a suspension bridge. These objects are,—1st, the obtaining a roadway across a river in a position where it is necessary to allow the passage of vessels beneath it, and where it is not possible to form piers or abutments sufficiently close together to allow of an ordinary arch being constructed. 2d, the judicious arrangement of the suspending chains, rods, and roadway bearers, to effect the greatest firmness and rigidity with the least expenditure of material.

The different forms may be arranged under the following heads. First,—those in which the planking of the roadway, (except a small portion near the abutments,) rests solely on the main suspending chains, as in Chinese bridges generally, and some in South America.

Second,—those in which the roadway side beams, carrying the planking, railing, &c., are only connected with the main suspending chains by vertical rods, as in the Menai Bridge and numerous others.

Third,—those in which the roadway platform is entirely supported by ropes, chains, or wires proceeding obliquely from the top of the abutments, as in some bridges of rope, canes, or bamboos in Asia, and light wire bridges in Europe.

Fourth,—those in which the roadway platform is partly supported by ropes, chains, or wires proceeding obliquely from the top of the abutments, partly by rods descending obliquely from the main chains, and partly by the main suspending chains themselves; which last diminishing in weight as they approach the middle of the span, are linked to the central portion of the roadway by short rods, which being nearly in continuation of the upper parts of the main chains, would, if strong enough, support that part of the roadway, and complete the curve, rendering the central link of the chain nearly unnecessary.

In all suspension bridges, chains are carried from the top of the abutments to the rear, and called back chains. There is one of these to each of the bridge chains, whether they carry the rods on each side, as in those of the second class, or go directly to the platform, as in the third and fourth classes. These back chains are connected with links secured on the top of cast iron saddles on the abutments at one end, and firmly bolted to cast iron anchor plates or blocks of masonry in the solid ground or rock at the other.

In the annexed plate is shown an elevation of the Niagara Falls Suspension Bridge, constructed by John Roebling, C. E. of the United States. This bridge has a span of 821 feet 4 inches, from centre to centre of towers. Its form is a slightly curved hollow beam or box, of a depth of 18 feet; width of bottom 24 feet, and of top 25 feet. The lower floor is used for common travel, while the upper is appropriated to railway business and sidewalks. The two floors are connected by two trusses of a simple construction, so arranged that its resisting action operates both ways, *up* as well as *down*. The suspenders are 5 feet apart. The beams of the upper and lower floor are connected by posts arranged in pairs, leaving a space between for the admission of the truss rods, which extend each way to the fourth pair of posts at an angle of 45°. These rods therefore cross each other and form a diamond work. They are 1 inch diameter, their screw ends 1⅛ inch.

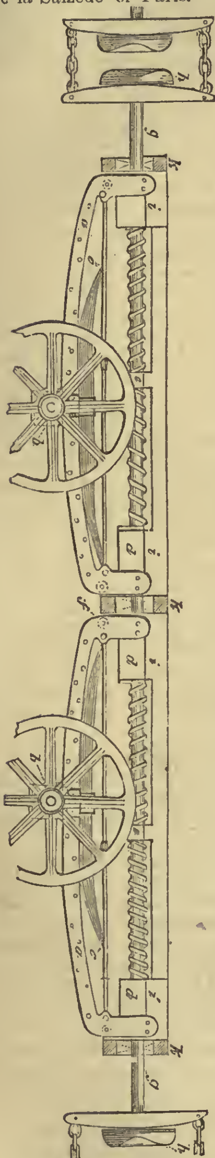
There are 4 cables of 10 inches diameter, each composed of 3,640 wires of small No. 9 gauge, 60 wires forming one square inch of solid section, making the solid section of each cable 60.40 square inches, wrapping not included. Each of the four large cables is composed of seven smaller ones, which are called *strands*. Each strand contains 520 wires; one of these forms the centre, the six others being placed around it; the ends of the strands are passed around and confined in cast-iron shoes, which also receive the wrought iron pin that forms a connection with the anchor chains. During the wrapping process the whole mass of wire was saturated with oil and paint, which, together with the wrapper, will protect the cables effectually against all oxidation. There are 64 diagonal stays, of 1⅝ inch diameter rope, above the floors, equally distributed among the four cables. They are fastened to the suspenders by small wrappings, so as to form staight lines; they are not continued over the towers to the anchorage, but are secured to the saddles, and allowed to move with them. To the under side of the lower floor 56 stays are attached, which are anchored in the rocks below, and occupy positions calculated to insure against horizontal as well as vertical motions. The anchorage of the back chains was formed by sinking 8 shafts into the solid limestone rock that here composes the uppermost stratum of the cliffs. Three of the pits on the New York side are sunk to a depth of 25 feet. The fourth one, south-east, was sunk only 18 feet, on account of the great influx of water, and difficulty of baling. The surface of the rock on the Canada side being 10 feet higher than on the New York side, the depth of the shafts was increased that much, and the height of the towers above reduced in proportion. Each shaft has a cross section of 3 × 7 feet, enlarged at the bottom to a chamber of 8 feet square. The anchor chains are composed of 9 links, all of which are 7 feet long, except the uppermost or last one, which is 10 feet. The first or lowest link is composed of 7 bars, 7 × 14 inches, and is secured to a cast-iron anchor plate by a pin of 3½ inches diameter ground upon its seat. The next link is composed of 6 bars of the same size, and 2 half bars on the outside. The aggregate section of each is 60 superficial inches; from the fourth link up, the link on the chain curves and the section is gradually increased to 93 superficial inches.

On the top of each column a cast-iron plate was laid down, well bedded in cement, 8 feet square

and 2½ inches thick, and strengthened by three parallel flanges for the reception of two independent saddles. Each saddle rests on ten cast-iron rollers, 5 inches in diameter and 25½ inches long, placed close together. The ordinary pressure upon each tower being about 500 tons, makes each roller bear 25 tons. These rollers admit of a slight movement of the saddles, whenever the equilibrium between the land and the suspension cables is disturbed, either by changes of temperature or by passing trains.

The success of this extraordinary bridge may now be considered as established. The trains of the New York Central, and of the Great Western Rail Road in Canada, have been crossing regularly since its completion, averaging over thirty trips per day.

BRONZING. *Improvements in the Brassing and Bronzing the surfaces of steel, iron, &c.*, by Charles de la Salzede of Paris. This invention consists in coating cast-iron, steel, lead, zinc, and tin, with brass or bronze, by means of a galvanic battery. The solution to be used consists of 5,000 parts, by weight, of distilled water, 610 parts subcarbonate of potass. 25 parts chloride of copper, 48 parts of sulphate of zinc, 305 parts of nitrate of ammonia, and 12 parts of cyanide of potassium The cyanide of potassium is dissolved by itself, in about 120 parts of distilled water taken from the above quantity. The other salts above mentioned (except the nitrate of ammonia) are then added to the remainder of the water, and the mixture is heated to from 144° to 172° Fahrenheit, when they are entirely dissolved the nitrate of ammonia is added, and the solution allowed to stand 24 hours; the solution of the cyanide of potassium is then added, and the whole allowed to stand till it is quite clear; the clear solution is then to be drawn off with a siphon, and put in the decomposing trough. The subject to be covered with brass is then to be attach- to the zinc pole of a battery; and to the other pole of the battery a large plate of brass is to be attached, which must be also immersed in the solution. The battery must, the patentee says, be a powerful one: he advises to use Bunsen's or Grove's. When it is intended to bronze, instead of the 48 parts of sulphate of zinc, 25 parts of chloride of tin must be used; the other ingredients are to remain the same. Another solution recommended by the patentee, consists of 5,000 parts of distilled water, 15 parts of chloride of copper, 35 parts of sulphate of zinc, 500 parts of subcarbonate of potass, and 50 parts of cyanide of potassium for brassing; and for bronzing, 12 parts of chloride of tin, instead of the 35 parts of sulphate of zinc; this solution, the patentee says, must be used at a temperature of from 25° to 36° cent. The proportions, the patentee says, may be varied within certain limits.



Section of Bergin's Buffing Apparatus.

BUCKET-WHEELS. See WATER-WHEELS.

BUFFING APPARATUS. A contrivance for receiving the shock of a collision between railway carriages, consisting of powerful springs and framing.

The buffing apparatus first used upon the Liverpool and Manchester Railway consisted of elliptic iron springs, or bows, of several thicknesses, placed transversely across the middle of the frame-work of the carriage which received the shock of whatever blows or jerks the buffer-heads might receive, by the aid of rods communicating with the same. Mr. Bergin, of Dublin, contrived an improved buffing apparatus for the carriages of the Dublin and Kingstown Railway.

It is supported upon the axles of the wheels, and is totally unconnected with the frame of the carriage, whereby it does not partake of the rise and fall of the latter, according to the weight acting upon the vertical springs; and two strong iron rods are passed through the whole length of the carriage, which rest upon small rollers, to which the buffer-heads are attached, spiral springs being wound round them, which receive the effect of all shocks, by the help of collars formed upon the rods, and the introduction of stops to the springs.

On American Rail Road Cars the coupling and buffing apparatuses are usually combined in one. The cars are attached to each other by a single link of chain, inserted in the jaws of the buffer-heads, and retained by iron pins passing down through the buffer-heads and links. This arrangement is sometimes made self-acting, to obviate the necessity of standing between the cars to insert the links and pins. The buffing bars are of iron, with convex heads at their points of junction, and bear against springs, attached to the bottom of the car, the draught acting from the centre.

To obviate the oscillations of cars and wagons, which produce strains on the axles and other parts, injury to the road-way, and deterioration to freight; the connection between the parts of a train should resemble as much as possible the jointing of the vertebræ in an animal's back-bone by which means the lateral action of a car would be neutralized by the support of the neighboring ones. The methods at present adopted for coupling and drawing trains are open to great improvement. The mode of coupling cars in freight trains without spring-buffers or draw-bars is liable to lead to accidents from the play which must necessarily be allowed between the cars to admit of their going round curves, since each time the speed is slackened, the cars close up, and at a fresh start the chains

are exposed to a sudden jerk. The best mode of connection is the coupling screw, by means of which the cars are drawn together so that the buffers are pressed into close contact, and their springs a little compressed. In this manner the train is formed into one complete column, and the change of speed to which it is subject does not produce the partial collision mentioned.

BUHL-WORK, OR BOOL-WORK. The terms appear to be corrupted from Boule, the name of the original inventor, and now refer to any two materials of contrasted colors inlaid with the saw. In France this kind of inlaid work is called *marqueterie.* It consists in representing flowers, animals. landscapes, and other objects, in their proper tints, by inlaying. It also includes geometrical patterns composed of angular pieces laid down in succession, as in ordinary veneering, and is chiefly used in ornamenting cabinet work. In buhl-work the patterns generally consist of continuous lines, as in the honey-suckle ornament. Two pieces of veneer of equal size, such as ebony and holly, are scraped evenly on both sides, and glued together, with a piece of paper between. Another piece of paper is also glued outside one of the veneers, and on this the pattern is drawn. A small hole is then made for the introduction of the saw, a spot being chosen where the puncture will not be noticed.

The saws used in buhl-work are of peculiar construction, and of different sizes. The frames are of wood or metal; three pieces of wood halved and glued together constitute the three sides of a rectangle; two pieces are then glued upon each side, each at an angle of 45° across the corners; the whole when thoroughly dry is then cut round to the desired curve. Screws for giving tension to the blade are commonly added, but seldom used, as the frame is only sprung together at the moment of fixing the saw, and by its reaction stiffens the blade. A handle is attached to the saw frame at the bottom. In the piercing saw of metal the height from the blade to the frame is usually eight inches, and in the ordinary buhl-saw of wood from twelve to twenty inches, to avoid the angles of large work.

The buhl-cutter sits astride a horse or long narrow stool; the work held in the left hand, is placed in a vice at one extremity of the horse, having a flexible jaw under the control of the foot; the saw, which has been previously inserted into the hole in the veneers, and fixed in its frame, is grasped in the right hand, with the fore-finger extended, to support and guide the frame. "The several lines of the work are now followed by short, quick strokes of the saw, the blade of which is always horizontal; but the frame and work are rapidly twisted about at all angles, to place the saw in the direction of the several lines. Considerable art is required in designing and sawing these ornaments, so that the saw may continue to ramble uninterruptedly through the pattern, whilst the position of the work is as constantly shifted about in the vice, with that which appears to be a strange and perplexing restlessness. When the sawing is completed, the several parts are laid flat on a table, and any removed pieces are replaced. The entire work is then pressed down with the hand, the holly is stripped off in one layer with a painter's palette knife, which splits the paper, and the layer of holly is laid on the table with the paper downwards, or without being inverted. The honey-suckle is now pushed out of the ebony with the end of the scriber, and any minute pieces are picked out with the moistened finger; these are all laid aside; the cavity thus produced in the ebony is now entirely filled up with the honey-suckle of holly, and a piece of paper smeared with thick glue, is then rubbed on the two to retain them in contact. They are immediately turned over, and the toothings or fine dust of the ebony are rubbed in to fill up the interstices; a little thick glue is then applied, and rubbed in, first with the finger, and then with the pane of the hammer, after which the work is laid aside to dry." When dry it is scraped at the bottom, and is then ready to be glued on the box or furniture to be ornamented, as in ordinary veneering; it is afterwards scraped and polished. An ebony honey-suckle may be inserted in a ground of holly in the same manner; and these form the *counter* or *counterpart-buhl*, in which the pattern is the same, but the color reversed.

Three thicknesses of wood may be glued together, as rosewood, mahogany, and satin-wood, which, when cut through, split asunder, and recombined would produce three pieces of buhl-work, the grounds of which would be of either kind with the honey-suckle and centre of the two other colors respectively. These are called "works in three woods," and constitute the general limit of the thicknesses. Buhl-works of brass and wood are also sometimes made by stamping instead of sawing.

BULLETS. *Manufacture of by Rolling.* At the Arsenal, at Woolwich in England, they now manufacture leaden bullets by drawing and compression. These bullets have the advantage of being without *blows* or air cavities, and are rolled out of round bars of lead, which are passed between rolls formed like the roulettes used for ornamental work on the lathe. The rolls are constructed with hemispherical cavities, each one of which forms one-half of the ball, whilst the corresponding cavity forms the other half; the bullets are then finished by removing the extra metal, and being rolled together in a barrel.

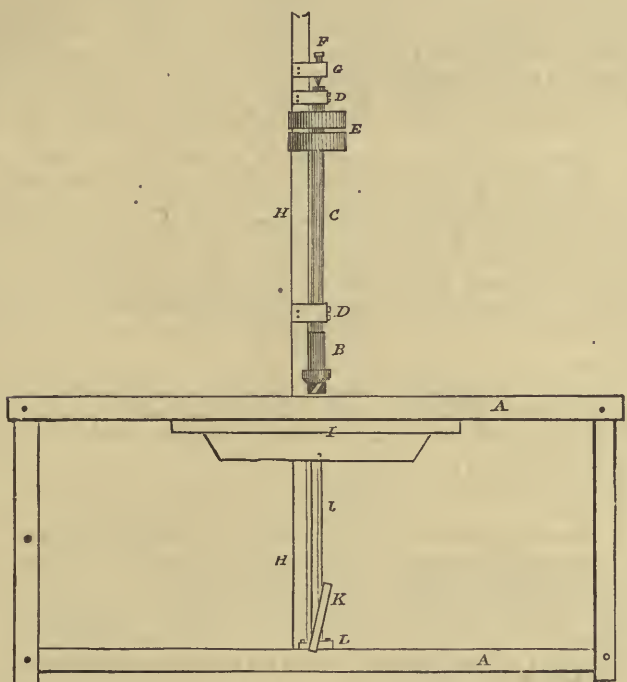
The bars of lead from which the balls are compressed are cast in moulds, 36 inches in length by 75 in diameter. These bars are then brought to the machinery, and are first passed through a roller, which condenses the lead, and prepares it for the second operation, that of compressing it into shape or form for the die. Thirdly comes the die. which by its regular movement forward is brought into contact with the masses of lead prepared, and as the die recedes, a boy moves up the bar for its next movement, and so on; following it up with other bars of lead arranged at his right hand, so that the die in its forward movement always finds its work prepared, and leaves the balls formed in a belt of lead. The fourth and last operation is that of cutting the balls out of the belt, which is done by a punch, exactly the diameter of the bullet, and which is brought over it and worked by a boy with his foot. The advantage of the compressed over the cast bullet is its perfect solidity; whereas the cast has a flaw, more or less, in every bullet. The belted or rifle ball should, therefore, always be made by compression. The following is a description of a machine invented by Wm H. Ward, of Auburn, N. Y., for manufacturing bullets from lead wire. The wire is coiled upon rests at the top of the machine, and suspended by means of arches, from which the lead is fed downwards into the machine, where it is measured and cut off as required for each bullet, after which it is forced forward into dies, and formed into the desired shape by compression. This machine is capable of making musket, rifle, and pistol

elongated, hollow, and conical expansion bullets; also round or shell balls, all at the same time. Each corner being double with two sets of dies and punches, gives eight bullets to one revolution of the machine. The machine may be worked up to twenty-five turns in a minute, which is equal to 200 bullets per minute, or 12,000 per hour.

BULLET-WOOD. See Woods, *varieties of*.

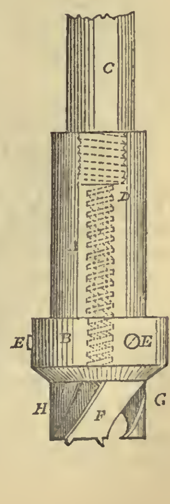
BUNG-CUTTING MACHINE. We here present two views of a machine invented by Messrs Dowdy & Sweet, No. 35 Cross-street, of this city. Fig. is a side elevation, and fig. a view of the cutter-stock and cutters. A is a stout table. H is a strong upright-post in the middle of the table. To this post the cutter-shaft C is secured by proper bearings D D, to allow it to revolve. F is a screw which passes through a bearing G, into an opening in the head of N. J is an elevating bed or rest for the plank that is to be cut into bungs. It is fixed on a treadle J, by a foot-spring K; when pressed upon towards L, the bung-bed is elevated through an opening in the middle of the

620.



table, and as the foot presses K, so is the plank fed up to the cutter till the bung is cut, when the foot being released, the bung is driven out by a spiral spring, which will be better understood by Fig. 621.

621.



A is the cutter-stock. It is of a cylindrical form, with an opening through the centre, and a thread a short distance at the upper end to screw in the shaft C. In the centre of the cutter-stock is a spindle with a spiral spring on it, represented by D. The spring does not reach to the ends of the spindle. By an opening in C, the shaft is allowed to pass into it, when the plank is fed into the cutters; but when the bung is cut, this spiral spring in the centre of the cutter-stock recoils as the feed-table is lowered, and throws out the cut bung. This is the object and use of the interior spiral spring and spindle. G F H are the cutters. Each is a distinct piece, and each performs a different office. They are all set on to the cutter-stock, which is turned on the outside, leaving them to sit around it like a ring, where they are covered with a snug collar B, and a screw E E, for each cutter, secures them to the cutter-stock. The inside of the cutters is like a cup, and they are arranged almost like screws of different pitch. F has two little spurs on it; one on the inner side, and the other on the outer. These cut the cresses of the groove in the plank for the bung, when H follows after and scoops it out, cutting on the outside of the bung. Both of these cut straight without any taper. G is the taper cutter. It is graduated in the edge to the bottom of the cutter-stock; therefore it gradually planes the taper of the bung, after the other two cutters have done the rough work. This makes the work easy on the machine, which cuts out about 20 bungs per minute, hand fed, with great ease. On the bottom of the stock, in the inside of the cutters, there is a small knife that rims off the edge of the bung. This machine has been in operation successfully for some time.

BURNETTIZING, the process for preventing the rapid decay of timber, by the use of chloride of zinc. The liability of nearly all kinds of timber in common use to rapid decay, when exposed to alternate wet and dry, or when placed in damp and badly ventilated situations, has led to various devices for the purpose of increasing its durability under such circumstances.

In 1838, a patent was granted in England to Sir William Burnett, for a process for preventing decay in certain vegetable and animal substances by the use of chloride of zinc. This process, called Burnettizing, has been extensively used in England as a preventive of the decay of timber; and it has been more extensively used in this country for the same purpose than any other process. No patent was taken out for the United States. It was first introduced at Lowell, Massachusetts, where, in 1850, the Proprietors of the Locks and Canals on Merrimac River, at the joint expense of the manufacturing companies, erected the necessary apparatus for carrying on the process. Although it is not in all cases a preventive of decay, the advantages are more than sufficient to justify its application to most kinds of timber in common use, when placed in situations favorable to rapid decay. It has also a distinct effect in rendering wood less liable to warp and crack when placed in dry situations.

The apparatus at Lowell consists of a cast-iron cylinder, in which the timber to be prepared is placed; this cylinder is sixty feet long, and five feet diameter inside, with one head movable; the iron generally an inch thick. A pair of rails, about two feet gauge, are laid in the bottom of the cylinder, and also on the same line and level, about seventy-five feet outside the cylinder; a low truck, about sixty feet long, runs on these rails. When it is required to charge the cylinder with timber, this truck is drawn out, loaded, the load chained down to prevent its floating, and the truck then drawn into the cylinder.

A little below the level of the cylinder, and parallel to it, is placed a wooden cistern, to hold the solution while the cylinder is being loaded and unloaded, and at times when the apparatus is not in use; this cistern is about fifty feet long, seven feet wide, and four feet deep, and was originally constructed for Kyanizing by immersion. The air-pump is twelve inches in diameter, and three feet stroke. The force-pump four inches in diameter, and two feet stroke. The pumps are worked by a small steam engine of about fifteen horse-power, which also works the windlass by which the truck is drawn in and out of the cylinder. The boiler of the engine is also used in winter to supply steam to thaw frozen timber; this is done by admitting steam into the cylinder, charged with the frozen timber, for several hours before the vacuum is obtained. The steam engine and boiler are both much larger than necessary for these purposes.

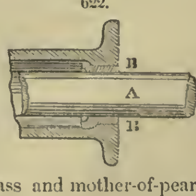
The process is as follows:—

	Time occupied.	
	Hours.	Min.
"The truck being outside the cylinder, is unloaded and reloaded with about seven thousand feet, board measure, of lumber, usually of various kinds and dimensions; from one to two hours is usually thus occupied, depending upon the dimensions and variety of sizes,—average, say - - - - - - - - - -	1	30
"Drawing in the truck and packing cylinder head - - - - - - -		15
"Exhausting the air, and maintaining a vacuum of twenty-seven or twenty-eight inches of mercury - - - - - - - - - - - - - -		45
"Changing pumps, and at the same time filling the cistern by atmospheric pressure from the cistern, with a solution of one hundred parts of water and one and a half parts of dry chloride of zinc by weight, and getting up the pressure in the cylinder to one hundred and thirty pounds to the square inch above the atmosphere - - - -		20
"The pressure of one hundred and thirty pounds to the square inch above the atmosphere is maintained - - - - - - - - - - - - -	2	30
"Draining off the surplus solution by gravitation from the cylinder to the cistern -	1	45
"Unpacking head and drawing out truck - - - - - - - -		15
"Time occupied in preparing one batch," - - - - - - - - - -	7	20

By allowing the solution to drain off during the night, two batches per day are easily done.

Whenever it is required to prepare large quantities of timber, uniform in kind and dimension, such as railroad sleepers, an improvement in the above process would be, to maintain the pressure until a certain quantity of the solution was taken up; but with the great variety in kind and dimension usually prepared at the same time, this is impracticable; as the lumber of small thickness gets more than its due proportion, and the pressure is kept up so long in order that the larger sizes may be sufficiently saturated. The chloride of zinc is received from the manufacturers in the form of concentrated solution containing about 55 per cent. of the dry chloride. The amount taken up by the wood varies very much, depending upon the kind, dimensions, and dryness of the wood; as the process is conducted at Lowell, it varies from about ten pounds to forty pounds of the concentrated solution to a thousand feet board measure, or from two to eight ounces to a cubic foot.

622.



BUSH. A piece of metal, usually made of hard brass, and fitted into a plumber-block, in which the journal turns; they are also sometimes termed *pillows*, and the blocks, *pillow-blocks*. The guide of a sliding-rod is also termed a *bush*. Thus, in Fig. 622, A is the piston-rod, B B the bush.

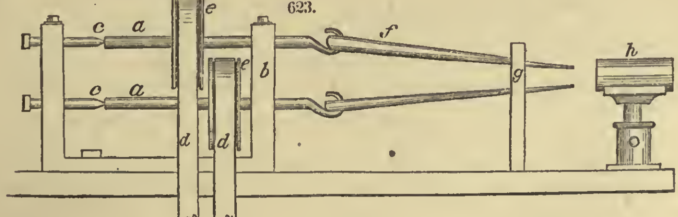
BUSHES, *metal for lining*. See Details of Engines.

BUTTON MACHINERY. Buttons may be divided into two general classes,—those with shanks, or loops of metal, for the purpose of attaching them to garments, and those without shanks; and each class is manufactured from a great variety of materials, and by a variety of methods. Of buttons with shanks the greater number are composed of metal, although glass and mother-of-pearl are also employed for the purpose. Metal buttons are formed in two different ways, the blanks or bases of the buttons being either cast in a mould, or stamped out of a sheet of metal; the former method is generally employed for making white metal-buttons, and the latter for plated and gilt buttons. To cast

buttons, a great number of impressions of the pattern of the button are taken in sand, and in the centre of each impression is inserted a shank, the ends of which project a little above the surface of the sand, and fused metal is poured over the mould. When cool, the buttons are taken from the moulds, and after being cleansed from sand by brushing, are placed in lathes, the edges are turned, the face and back smoothed, and the projecting part of the shank also turned. The buttons are then polished by rubbing the faces upon a board spread with rotten-stone of different degrees of fineness, and afterwards by being held against a revolving board covered with leather, upon which is spread a very fine powder of the same material; finally, they are arranged on a sieve or grating of wire, and immersed in a boiling solution of granulated tin and cream of tartar, by which means their surfaces become covered with a thin layer or wash of the metal, which improves their whiteness without injuring their polish. The blanks of plated buttons are cut by a fly-press out of copperplate, coated on one side with silver. They are then annealed in a furnace, and afterwards stamped by the descent of a weight, as in a pile-driving machine, the die being fixed in the lower surface of the weight. The soldering of the shank is performed on each button separately, by the flame of a lamp and a blowpipe: the edges of plain buttons are next filed smooth in a lathe, and the buttons are afterwards boiled in a solution of cream of tartar and silver; they are then placed in a lathe, and the backs brushed, and afterwards burnished with blood-stone. The metal used for gilt buttons is an alloy of copper and zinc. This metal is rolled out into sheets, and the blanks stamped out, which are then planished, if intended for plain buttons; but if for figured buttons, the impression is now given. The shanks are next attached, which is effected as follows: each blank is furnished with a pair of small spring tweezers, which hold the shank down upon it on the proper place, and a small quantity of solder and resin is applied to each. They are then exposed upon an iron plate to a heat sufficient to melt the solder, by which the shank becomes fixed to the button; and whilst still warm they are plunged into nitric acid, to remove the oxide formed on the surface by the heat employed in soldering the shanks. They are then placed in a lathe. the edges rounded, and the surfaces rough-burnished, which renders them ready for gilding. Five grains of gold are fixed by act of parliament, in England, as the least quantity to be employed in gilding a gross of buttons of one inch in diameter. An amalgam is formed of gold and mercury, and the buttons are placed in an earthen vessel along with the amalgam, together with as much aquafortis as will moisten the whole, and the mixture is stirred with a brush until the buttons are completely whitened. To dissipate the quicksilver the buttons are shaken in an iron pan, placed over a fire, until the quicksilver begins to melt, when they are thrown into a felt cap, and stirred with a brush, to spread the amalgam equally over their surfaces; after which, they are returned to the pan, and the mercury volatilized completely by the increased heat, leaving the gold evenly spread in a thin film over the surface of the buttons; they are then burnished in a lathe, which completes the operation. The better sort of buttons undergo the gilding process twice or thrice, and are distinguished accordingly as "double" or "treble gilt." Glass buttons are formed of glass compressed, while in the fluid state, in moulds, in which the shank is inserted, and when the glass becomes cold, the shank is firmly retained in its place. In mother-of-pearl buttons the method of inserting the shank is extremely ingenious: a hole is drilled at the back, and undercut—that is, larger at the bottom than at top; and the shank being driven in by a steady stroke, its extremity expands; on striking against the bottom of the hole, it becomes firmly riveted into the button, forming a kind of dove-tail joint.

Buttons without shanks are of two kinds; the first are simply disks of horn, bone, wood, or other material, with four holes drilled through the face, for the purpose of sewing them to the garment. Horn buttons of this description are made from cow-hoofs by pressing them into heated moulds. The hoofs having been boiled in water until they are soft, are first cut into plates of the requisite thickness, and after into squares of the size of the diameter of the button, and afterwards reduced to an octagonal form by cutting off the corners. They are then dyed black by immersing them in a caldron of logwood and copperas mixed. A quantity of moulds somewhat resembling bullet-moulds, and each furnished with a number of steel dies, are then heated a little above the point of boiling water, and one of the octagonal pieces of horn is placed between each pair of dies, and the mould being shut is compressed in a small screw-press, and in a few minutes, the horn becoming softened by the heat, receives the impression of the die, after which the edges are clipped off by shears, and then rounded in a lathe. The holes in buttons of this description are drilled by means of a lathe, represented in the annexed engraving. Four spindles, of which two only, *a a*, can be seen, are supported in bearings at *b*,

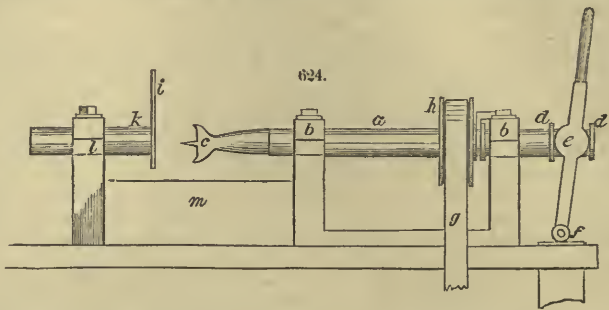
623.



and by the centre points *c c* are made to revolve with great velocity by means of two bands *d d* passing over pulleys *e e* fixed upon each of the spindles, each band driving two spindles, and receiving motion from a wheel worked by a treadle. At the end of each of the spindles *a*, is a hook uniting them to four other spindles *f f* by similar hooks at one end, the other end of the spindles passing through four small holes in the plate *g*, and the projecting points being formed into small drills. The button is placed in a concave rest *h*, and pushed forward against the drills by a piece of wood. The standard *g* can be

exchanged for another with holes more or less apart, and the rest *h* can be set at any height to suit different-sized buttons. As the spindle-holes in the plate *g* are nearer together than the holes in the standard *b*, the spindles *f f* converge; the hooks in the spindles are therefore necessary to form a universal joint. The second description of buttons without shanks consists of thin disks of wood or bone, called moulds, covered with silk, cloth, or other similar materials. The bone for the moulds is made from refuse chips of bone sawed into thin flakes, and brought into a circular form by two operations, illustrated by the accompanying engraving. On one end of the spindle *a*, which revolves in bearings

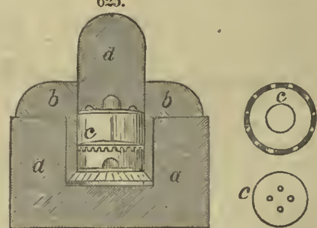
624.



at *b b*, is screwed a tool *c*, and on the other are two collars *d d*, between which a forked lever *e* embraces the shaft, the fulcrum of which is at *f*. The spindle *a* is put in rapid motion by a band *g* passing over the pulley *h*, and over a band-wheel worked by a treadle; and the workman, holding the material *i* for the mould in his right hand, against a piece of wood *k* firmly held down in the iron standard *l* by two screws, by means of the lever held in his left hand, he advances the tool *c* against the material *i* of the mould; the central pin of the tool drills a hole through the centre of the intended mould, whilst the other two points describe a deep circle cutting half through the thickness of the material, and the flat surface is cut smooth by the intermediate parts of the tool. The tool is then drawn back a little by the lever *e*, and the material shifted to bring a fresh portion of the surface opposite the tool, and when as many moulds as the plate of the material will afford, are thus half cut through, the other side is presented to the tool, and the central point of it being inserted in the hole made in the first part of the operation, the other two teeth cut another deep circle exactly opposite the former one through the remaining substance of the material, and the mould is left sticking on the tool; by drawing back the lever *e* the tool recedes, and the mould, meeting a fixed iron plate, is pushed off the tool, and falls into a small box *m*.

Covered buttons having come into very general use, various improvements have been introduced in the manufacture of them, and patents for this purpose have been granted to various parties. The following is Mr. Sanders' method of making covered buttons: a piece of the material with which the mould is to be covered is cut of a circular shape, somewhat larger than the intended button; upon this is placed a disk of card of the exact size of the button, and next a disk of paper coated with an adhesive composition, which will become soft and sticky by heat; and upon these is laid a button-mould *e*, having four holes, through which threads or strings have been passed to form the flexible shank. These circular disks being put together, are then laid over a cylindrical hole in a metal block *a*; this hole being exactly the size of the intended button, and the covering of the button being larger than the hole, when the disks are pushed down into the hole, the material of the covering will wrinkle up on the edges round the other disks. The tube *b b* is then introduced into the cylindrical hole, and its lower edge being bevelled inwards, will, as it is pressed down, gather the plaits of the cloth on the edge of the button; towards the centre is a metal ring or collar *c*, having teeth round its edge, somewhat like a crown-saw, which is now passed down the tube *b*, and driven with considerable force by the punch *d*, and the block *a* having been previously heated, the adhesive matter will be softened, and cause the several disks to stick together, which, when taken out and become cold, will be very firm and retain its shape.

625.



Button shanks are made by hand from brass or iron wire, bent and cut in the following manner: The wire is lapped spirally round a piece of steel bar. The steel is turned round by screwing it into the end of the spindle of a lathe, and the wire by this means lapped close round it till it is covered. The coil of wire thus formed is slipped off, and a wire fork or staple with parallel legs put into it. It is now laid upon an anvil, and by a punch the coil of wire is struck down between the two prongs of the fork, so as to form a figure 8, a little open in the middle. The punch has an edge which marks the middle of the 8, and the coil being cut open by a pair of shears along this mark, divides each turn of the coil into two perfect button shanks or eyes.

Harding's Improvements.—These improvements in the manufacture of buttons and other dress fastenings, consist in the arrangement and construction of the parts whereby they are secured to the dress, for which two separate methods are given. According to the first method, the button is formed with a shank of a single wire, which after projecting a sufficient length from the back of the button to pass

through the garment, is turned at right angles, and coiled in the form of a spiral in a plane parallel to that of the button. The spiral consists simply of about two turns, and terminates abruptly. On securing this button to the garment, the end of the spiral is inserted through a small eyelet hole just sufficient to admit the entrance of the wire; the button is then turned round, and the wire screwed through the hole in the garment until the whole of the spiral passes underneath the vertical shank then occupying the hole, and the button is thereby secured, in which position it is held until the button is drawn from the garment and turned in the contrary direction. This mode of securing dress fastenings is also applicable to other fastenings, such as clasps, &c., the mode of attachment of which is precisely similar, the spiral and shank being attached to the article in any suitable manner to occupy the proper position for the purpose.

The second fastening is for a similar purpose, but for securing the ordinary description of shank button, or other dress fastening having a suitable shank. It merely consists of a piece of doubled wire, so as to form an eye; the continuations of the wire form a hook and clasp pin after being threaded through the shank of the button; the pin portion is sprung into the hook part whereby the wire is securely retained in its position. The button shank is first introduced through an eyelet hole, and the fastening placed at the back as described.

BUTTON-WOOD. See Woods, *varieties of.*

BUTTRESS. A piece of strong wall that stands on the outside of another wall to support it, or applied as an ornament.

CABLE. See Chain Cable.

CALCINATION. The chemical process of subjecting metallic bodies to heat with access of air, whereby they are converted into a pulverulent matter, somewhat like lime in appearance. The term *calcined*, is, however, now applied to any substance which has been exposed to a roasting heat.

CALCULATING MACHINES. Machines of this kind are designed to produce arithmetical and other tables, which shall be rigorously correct. In navigation and the higher branches of astronomy the use of such tables is very great, and being constructed by human heads and hands, they all contain errors of greater or less magnitude. The principle upon which these machines are constructed may be described as follows. In the manner in which quantities are combined in the common system of numeration, the value of each figure is ten times greater than it would be if it occupied a position one place to the right. Thus, in the number 1829, although 9 is greater than 2, yet the 2 in this position represents a larger sum than the 9, because it occupies a place to the left of the 9. The quantities really expressed by the figures 1829 are 1000, 800, 20, 9; but in practice we omit the cyphers, and place the significant figures side by side, preserving their proper position from the right hand. If a wheel be constructed on whose axis is a pinion with leaves or teeth; if these teeth work into another set of teeth or cogs on the periphery of another wheel, and if the teeth on the latter wheel are just ten times as numerous as those on the pinion, this system being made to revolve, the pinioned wheel will revolve just ten times as fast as the other. This produces a kind of analogy between the decimal notation and the working of the wheels, for it takes 10 units to make up one figure or unit in the second place in common numeration, and it requires 10 revolutions of the pinioned wheel to impart 1 revolution to the larger wheel. This is the fundamental principle in calculating machines. In such machines there are a number of dial-faces, each marked with figures from 1 to 10; these dial-faces are fixed upon wheels, the teeth of which work into the pinions of other wheels, on which are similarly divided faces or discs, so that while one face indicates units, another indicates tens, a third hundreds, and so on. These wheels and dial-faces may be differently arranged in different machines, but the principle is the same in all.

A calculating machine, called the Difference Engine, was constructed by M. Babbage for the English government at an expense of £20,000, to be used in preparing logarithmical and trigonometrical tables. A valuable feature introduced into this machine is the power of printing the tables as fast as it calculates them. Another machine, called the Analytical Engine, was invented by the same gentleman, of greater power than the first. This contains a hundred variables, or numbers, susceptible of changing, and each of these numbers may consist of twenty-five figures. The distinctive characteristic of this machine, is the introduction into it of the principle which Jacquard devised for regulating, by means of punched cards, the complicated patterns of brocaded stuff. See Abacus.

CALEMBERG. See Woods, *varieties of.*

CALENDER. A machine used in the manufacture of cotton and linen goods. Calendering is the finishing process by which the goods are passed between cylinders or rollers, and made of a level uniform surface. The machine consists of a number of rollers contained in a massive frame-work; the rollers are connected with a long lever loaded with weights at the further extremity, by which or by means of screws almost any amount of force may be applied, and the surface texture of the cloth varied at pleasure. With considerable pressure between smooth rollers, a soft silky lustre is given by equal flattening of the threads. By passing two folds at the same time between the rollers, the threads of one make an impression on the other, and give a wiry appearance with hollows between the threads. The rollers are made of cast-iron, wood, paper, or calico, according to the uses for which they are designed. The iron rollers are sometimes made hollow for the purpose of admitting either a hot roller of iron, or steam when hot calendering is required. The other cylinders were formerly made of wood, but it was liable to many defects. The advantage of the paper roller consists in its being devoid of any tendency to split, crack, or warp, especially when exposed to a considerable heat from the contact and pressure of the hot iron rollers. The paper takes a fine polish, and being of an elastic nature, presses into every pore of the cloth, and smooths its surface more effectually than any wooden cylinder, however truly turned, could possibly do.

In a five rollered machine, the cloth coming from behind, above the uppermost or 1st cylinder, passes

between the 1st and 2d; proceeding behind the 2d, it again comes to the front between the 2d and 3d; between the 3d and 4th it is once more carried behind, and lastly brought in front between the 4th and 5th, where it is received and smoothly folded. At this time the cloth should be folded loosely, so that no mark may appear until it is finally folded in the precise length and form into which the piece is to be made up, which varies with the different kinds of goods, or the particular market for which the goods are designed. When the pieces have received the proper fold, they are pressed in a hydraulic press previous to being packed.

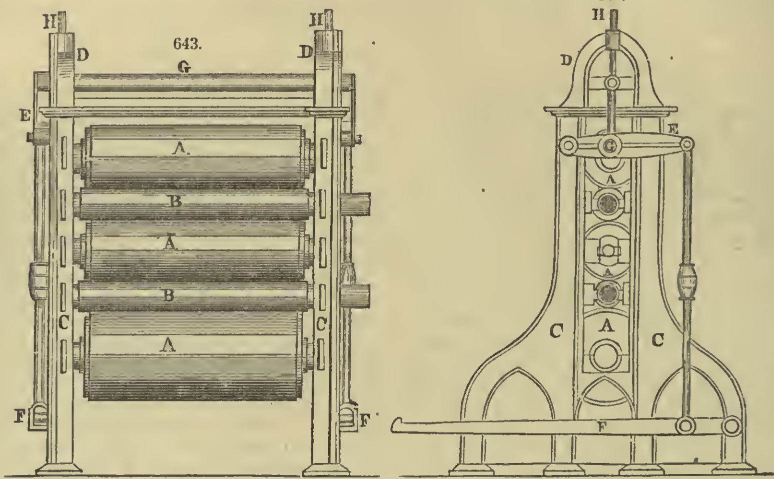
From the great weight of calendering machines it is necessary that they should be fixed on the basement floor. After the cloth has received its final gloss from these machines, it is taken to the cloth-room to be measured preparatory to being folded and packed for sale or transportation.

CALENDER WITH FIVE ROLLERS, Designed and Constructed by Messrs. A. More and Son, Glasgow. Fig. 644, an end view; Fig. 643, a side elevation; the same letters of reference denote the same parts in each view.

A A A, three cylinders or rollers made of paper, the construction of which will be noticed afterwards.

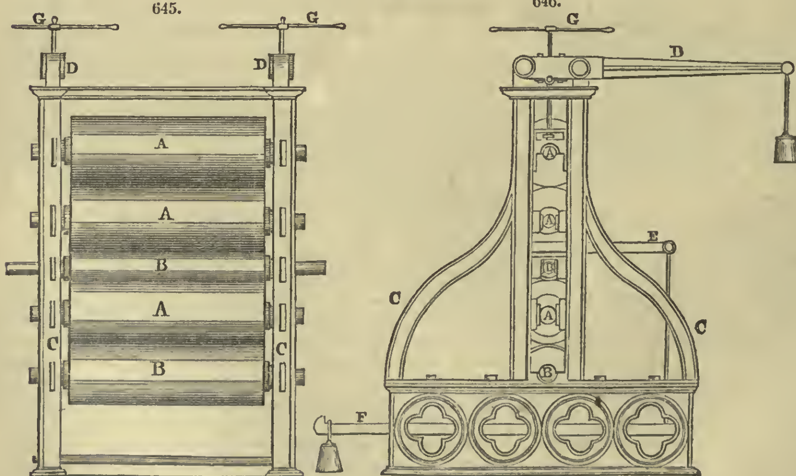
B B, two cast-iron cylinders, made hollow to allow of the introduction of hot bolts of iron within them; or of steam, when it is required or preferred.

643. 644.



SCALE.—1-4th inch = 1 foot.

645. 646.



SCALE.—1-5th inch = 1 foot.

C C, the two side-frames or cheeks, into which are fitted the several brass bushes for the cylinders to turn upon.

D D, top guides, into which the cross-head G, and elevating screws H H, work.

E E, top-pressure levers, connected by a strong rod of iron with the under-pressure lever F. This

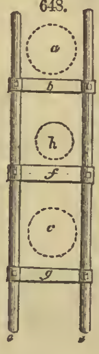
system of levers is connected with the cross-head G, by two strong links of iron. The elevating screws H H pass through the cross-head, and rest upon a strong cast-iron block, into which is fitted the brass bush of the top paper roller. By means of the screws, the cross-head and levers can be raised or depressed as required, and when the calender is working warm and requires to be stopped, the elevating screws are screwed up for the purpose of lifting the paper rollers off the hot cylinders, to prevent their being injured by the heat.

The construction of the paper rollers or cylinders is as follows: Upon each end of an arbor of malleable iron, of sufficient strength to withstand the necessary pressure without yielding, is fastened a strong plate of cast-iron, of the same diameter as the roller to be made; the plate is secured in its proper place by a ring of iron, cut in two, and let into a groove or check turned in the arbor. When the roller is finished, the annular pieces are kept in their groove by a hot hoop put upon the outside of them, and allowed to cool. A plate is fitted on the other end, of exactly the same size, and in the same manner.

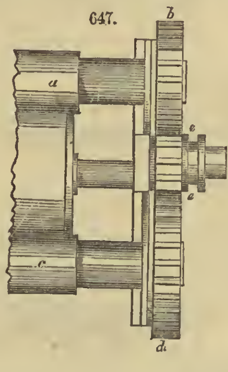
In building the rollers, one of the plates is taken off the arbor, but the other is allowed to remain in its place. The paper sheets of which the rollers are to be made, have each a circular hole cut in the centre of it, of exactly the same diameter as the arbor. The sheets are then put upon the arbor, and pressed hard against the fixed plate. When the arbor is filled with paper, it is put into a strong hydraulic-press, and pressed together,—always adding more paper to make up the deficiency caused by the compression, until the mass will press it no harder. The half rings are then put in their place, to prevent the plate from being pressed back by the elasticity of the paper. The roller is now to be dried sufficiently in a stove, the heat of which causes the paper to contract so as to be quite loose. The roller is then again taken to the press, and the unfixed plate being removed, more paper is added, and the whole again compressed, until the roller is hard enough for the purpose to which it is to be applied. It is next turned truly in the lathe till it acquires a very smooth surface.

The wood-cut, Fig. 647, shows the manner in which the calender is geered to make it a *glazing* calender. In this cut, *a* marks the top cylinder of the calender, upon which is keyed a spur-wheel *b*; and *c* is the under cylinder, upon which is also keyed a spur-wheel *d*. The intermediate or carrier-wheel *e e*, when drawn into geer, reduces the speed of the under cylinder *c*, one-fourth. Now, the cylinder *a*, being the one that gives motion to all the rollers, and revolving always at the same speed, the cloth

648.



647.



in its passage through all the rollers below the cylinder *a*, is carried through at a speed *one-fourth* less than if it passed only below the cylinder *a*; consequently, when it comes into contact with *a*, it is rubbed, and thereby *glazed*, in consequence of the cylinder *a* moving one-fourth quicker than the cloth, as above stated.

The wood-cut, Fig. 648, shows the manner in which the rollers are lifted clear of each other when the machine is stopped. In this, *e e* are two rods of iron, attached to the block or seat of the top roller; *b f g*, three bridges of malleable iron, capable of sliding upon the rods *e e*; but held fast upon the rods when once they are adjusted to their proper places by pinching screws. The bridge *b* is placed half an inch clear of the bearing of the cylinder *a*, when all the rollers are resting upon each other; the bridge *f* is placed *one inch* below the bearing of the paper roller *h*; and the bridge *g* is placed one inch and a half below the bearing of the cylinder *c*. When the pressure screws of the calender are lifted, the blocks of the top roller being attached to them, the rods *e e* are lifted also, and along with them the different rollers as the bridges successively come into contact with their respective bearings.

The manner of passing the cloth through the calender varies very much, according to the amount of finish required upon it. The various methods are accomplished by different arrangements of the geering, so that a calender calculated to do all the different kinds of finishing becomes a very complicated machine, on account of the quantity of geering required. For common finishing, the method of passing the cloth through the calender is as follows:—The cloth is passed alternately over and under a series of rails placed in front of the machine, so as to remove any creases that may be in it, and is then introduced between the lower roller A and cylinder B; returns between the lower cylinder B and the centre roller A; passes again between the central A and the upper B, and again returns between the top pair A, B, where it is wound off on a small roller, (hid in the drawings by the framing of the machine,) pressing against the surface of the top roller A. When this small roller is filled with cloth it is removed, and its place supplied by another, to be in succession filled as the motion of the machine progresses.

Water-Mangle with two copper, and three wooden rollers; designed and constructed by Messrs. A. More and Son.—This machine, Figs. 645 and 646, differs nothing in principle, and little in general construction, from the five-rollered calender above described, except in this—that it is intended for wet goods. It is drawn to a scale slightly less, but the views given and the lettering of the parts correspond to those of the preceding figures.

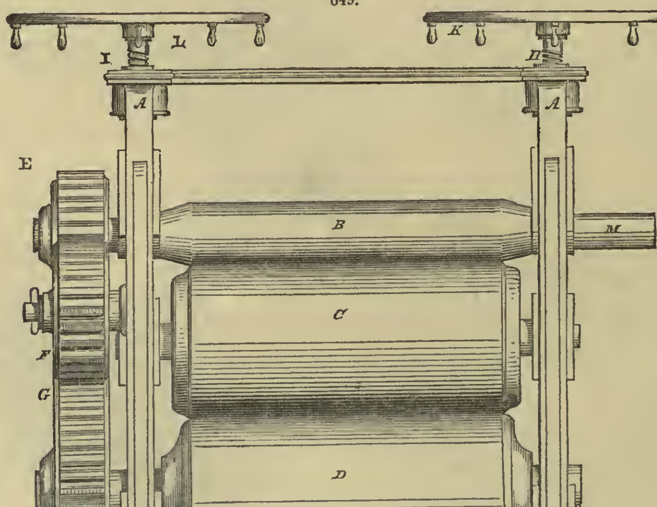
A A A, the three wooden rollers, and B B, the two copper rollers of the mangle. These last consist of a copper cover upon a cast-iron body, through which passes a wrought-iron arbor, differing from those of the wooden rollers in being round, whereas these are square between the bearings. The smaller of the two copper rollers, namely, the third in order, is in this arrangement the driver, the mangle being driven like the calender, by a system of reversing geer not shown in the drawings.

The pressure in the mangle is brought on by a system of levers, which differ slightly from that described. In this, indeed, there are strictly two distinct pressures: that brought on the axis of the middle roller by the lever E, which is connected by a link with the weighted lever F; and that transmitted through the whole system of rollers by the single-weighted lever D. The weight of this last is regulated by means of a set-screw, which turns in a nut in the jaws of the lever D, and bears upon the set-block which rests upon the arbor of the top roller. This pressure is thus transmitted downwards from the top roller throughout the whole set, and at the middle roller B is added to the pressure obtained by the lever E. By this arrangement, the pressure between the three under rollers is greater by the pressure of E, than it is between the upper pair; but, for very high pressure the lever D may be locked by set-pins and the set-screws turned down by the hand-wheel G, until the requisite degree of pressure is obtained.

The manner of passing the cloth through this machine is the same as that already described in the calender, with this single exception, that before the cloth enters between the lowest roller A, and the small cylinder B, jets of water from a pipe, perforated with small holes, extending the whole width of the machine, are allowed to play upon the cloth, so as to impart to it sufficient moisture for causing it to receive the requisite degree of smoothness preparatory to the starching process, and at the same time allow the cylinder B to free it from any impurities that may be remaining in it, by forcing them back with the expressed water.

CALENDER. *Description.* A, two cast-iron frames. B C D, three cylinders. E F G, three cog wheels. H I, two force-screws. K L, two fly-wheels with handles.

649.

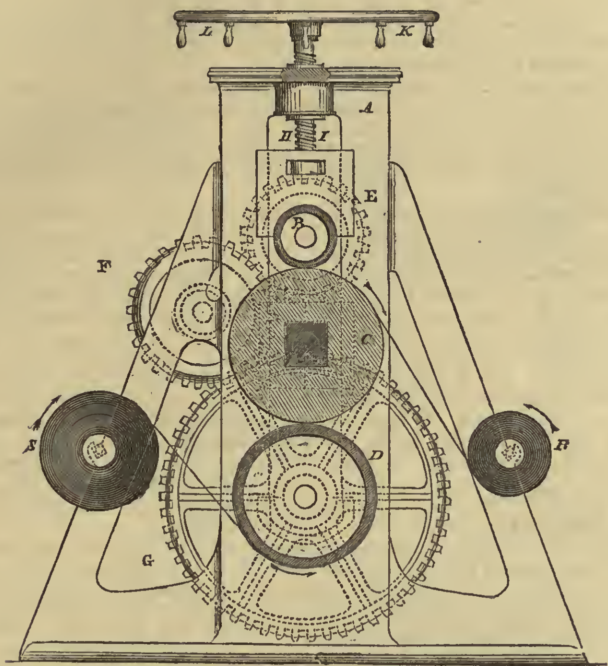


The cylinder B, which is in cast-iron, and hollow, is heated by another iron cylinder heated red hot. The material of the cylinder C is pasteboard, its axle is of wrought-iron. These three cylinders must be perfectly round and parallel.

The wheel F forms the communication between E and G, which rest upon the cylinders B and D. The relation of F to the circumference of the cylinders is such, that when the machine is set to work

these cylinders slide, causing friction, and thus give a gloss to the cloth. The friction is variable according to the nature of the tissue.

650.



In order to set the machine in motion, the fly-wheels K and L being turned in order to press the screws H and I against the pillows of the first cylinder B, the cloth is placed between the rollers in the direction indicated by the arrows.

CALICO PRINTING. The art of producing a colored patttern on cloth by the application of coloring substances. The processes employed are applicable to linen, silk, worsted, or mixed fabrics, although they are usually referred to cotton cloth or calico.

The invention of *cylinder* or *roller printing,* is attributed to two persons, one a Scotchman named Bell, the other named Oberkampf, a calico printer at Jouy in France.

The cylinders upon which the pattern is engraved, one cylinder for each color, are mounted on a strong frame-work, so that each cylinder revolves against two other cylinders, one of which is covered with woollen cloth, and dips into a trough containing coloring matter properly thickened, so that, as it revolves, it takes up a coating of color and distributes it over the engraved roller, which transfers the pattern to the cloth. The cloth to be printed passes over a large iron drum covered with several folds of woollen cloth, so as to form a somewhat elastic printing surface: an endless web of blanketing is made to pass round this drum, which serves as a sort of guide, and defence, and printing surface to the calico which is being printed. The superfluous color is removed from the engraved roller by a sharp-edged knife or plate usually of steel or gun-metal, called the *color doctor*, so arranged, that the color scraped off shall fall back into the trough; another plate of steel removes the fibres which the roller acquires from the calico.

As many as eight colors may be printed at once by one machine, but very great nicety of arrangement is required to bring all these rollers to bear upon the cloth, so as to print at the exact spots required for forming a complicated pattern.

The printing cylinders are of copper, and vary in length from 30 to 40 inches, according to the width of the calico; the diameter varies from 4 to 12 inches. Each cylinder is bored through the axis, and accurately turned from a solid piece of metal. To engrave a copper cylinder by hand with the multitude of minute figures which exist in many patterns, would be a very laborious and expensive operation, and the invention of Mr. Jacob Perkins in America, for transferring engravings from one surface to another by means of steel roller dies, has long been applied to calico printing with perfect success. The pattern is first drawn upon a scale of about 3 inches square, so that this size of figure being repeated a number of times will cover the printing cylinder. This pattern is next engraved in intaglio upon a roller of softened steel, about 1 inch in diameter and 3 inches long, so that it will exactly occupy its surface. This small roller which is called the *die*, is next hardened by heating it to redness in an iron case containing pounded bone-ash, and then plunging it into cold water, its surface being protected by a chalk paste. This hardened roller is put into a rotatory press, and made to transfer its design to a similar roller in a soft state called the *mill;* the design which was sunk in the die now appears in relief on the mill. The mill in its turn is hardened, and being put into a rotatory press, engraves or indents upon the large copper cylinder, the whole of the intended pattern.

It is often necessary to apply some substances to the cloth which shall act as a bond of union between it and the coloring matter. These substances are usually metallic salts called *mordants*, which have an affinity for the tissue of the cloth as well as for the coloring matter when in a state of solution, and form with the latter an insoluble compound. The usual mordants are alum, and several salts of alumina, peroxide of iron, peroxide of tin, protoxide of tin, and oxide of chrome. Mordants are useful for all vegetable and animal coloring matters which are soluble in water, but have not a strong affinity for tissues. The action of the mordant withdraws them from solution, and forms with them upon the cloth certain compounds which are insoluble in water.

To prevent the mordant or the coloring matter from spreading beyond the proper limits of the design, *thickeners* are used to bring it to the required consistency; the most useful are wheat starch and flour, but many other materials are used for this purpose. The colors, with the proper thickeners, are prepared in vessels furnished with steam jackets, for raising the contents to the required temperature.

There are eight different styles of calico printing, each requiring different methods of manipulation, and peculiar processes.

1. The *madder* style, (so called from its being chiefly practised with madder,) to which the best chintzes belong, in which the mordants are applied to the white cloth with many precautions, and the colors are afterwards brought up in the dye-bath. These constitute permanent prints. 2. The *padding style*, in which the whole surface of the calico is imbued with a mordant, upon which afterwards different colored figures may be raised, by the topical application of other mordants joined to the action of the dye-bath. 3. The *resist style*, where the white cloth is impressed with figures in resist paste, and is afterwards subjected first to a cold dye, as the indigo vat, and then to a hot dye-bath, with the effect of producing white or colored spots upon blue ground. 4. The *discharge style*, in which thickened acidulous matter, either pure or mixed with mordants, is imprinted in certain points upon the cloth, which is afterwards padded with a dark colored mordant, and then dyed, with the effect of showing bright figures on a dark ground. 5. *China blues;* a style resembling blue stone ware, practised with indigo only. 6. The *decoloring style*, by the topical application of chlorine or chromic acid to dyed goods. This is sometimes called a discharge. 7. Printing by steam, a style in which a mixture of dye extracts and mordants is topically applied to calico, while the chemical reaction which fixes the colors to the fibre is produced by steam. 8. Spirit colors; produced by a mixture of dye extracts, and a solution of tin. These colors are brilliant but fugitive.

The processes actually required for finishing a piece of cloth in the madder style, as for example, in producing a red stripe upon a white ground, are numerous. The bleached cloth is submitted to nineteen operations, as follows:—1. Printing on mordant of red liquor, (a preparation of alumina,) thickened with flour and dyeing; 2. Ageing for three days; 3. Dunging; 4. Wincing in cold water; 5. Washing at the dash wheel; 6. Wincing in dung-substitute and size; 7. Wincing in cold water; 8. Dyeing in madder; 9. Wincing in cold water; 10. Washing at the dash wheel; 11. Wincing in soap water containing a salt of tin; 12. Washing at the dash wheel; 13. Wincing in soap water; 14. Wincing in a solution of bleaching powder; 15. Washing at the dash wheel; 16. Drying by the hydro-extractor; 17. Folding; 18. Starching; 19. Drying by steam.

CALICO: *Machine for printing in four colors.* In this machine the pressure is normal, in all the engraved rollers, by the means of the levers P. These rollers are turned by a belt communicating with the prime mover. The regulators are adjusted by screws, to which are attached hands, indicating, upon dials, the space to be run by the rollers in order to reach the regulators: this is known without stopping the works.

The engraved rollers can be brought up to the pressing cylinder, or withdrawn from it, without changing the places of the color-vessels or of the scrapers, for all the different pieces fixed against the pillows on the turning pieces of the engraved rollers, move with these last. Finally, there is an apparatus placed behind the under cloth, the intermediate cloth, and the stuff to be engraved, by which the workman governs these three pieces at will.

The engraved rollers are sometimes made of copper, sometimes of brass, or of copper and tin. The first are to be preferred, being less apt to be injured; with such a cylinder 30,000 pieces can be printed with the most delicate patterns.

The brass cylinders will be injured in proportion to the acidity of the printing-mixture, the zinc being attacked. Those in whose composition tin is introduced are more hard, but also more difficult to engrave. Some of these cylinders are hollow, others are massive: either may be used.

The diameter of the cylinders varies from 0·23 to 0·82 feet, according to the option of the manufacturer, and also to the dimensions of the pattern.

The dimensions of the pressing-rollers make no difference in the impression: the lesser ones should, on certain considerations, be preferred, for the engraved rollers always yield under the pressure of the first, so that it becomes necessary to give a curve to the pressing-roller equal to that of the engraved; and as the pressure it exercises is inversely to the augmentation of its diameter, it becomes necessary to increase the weight on the subterraneous levers, thus giving still more chance to the engraved cylinders to bend.

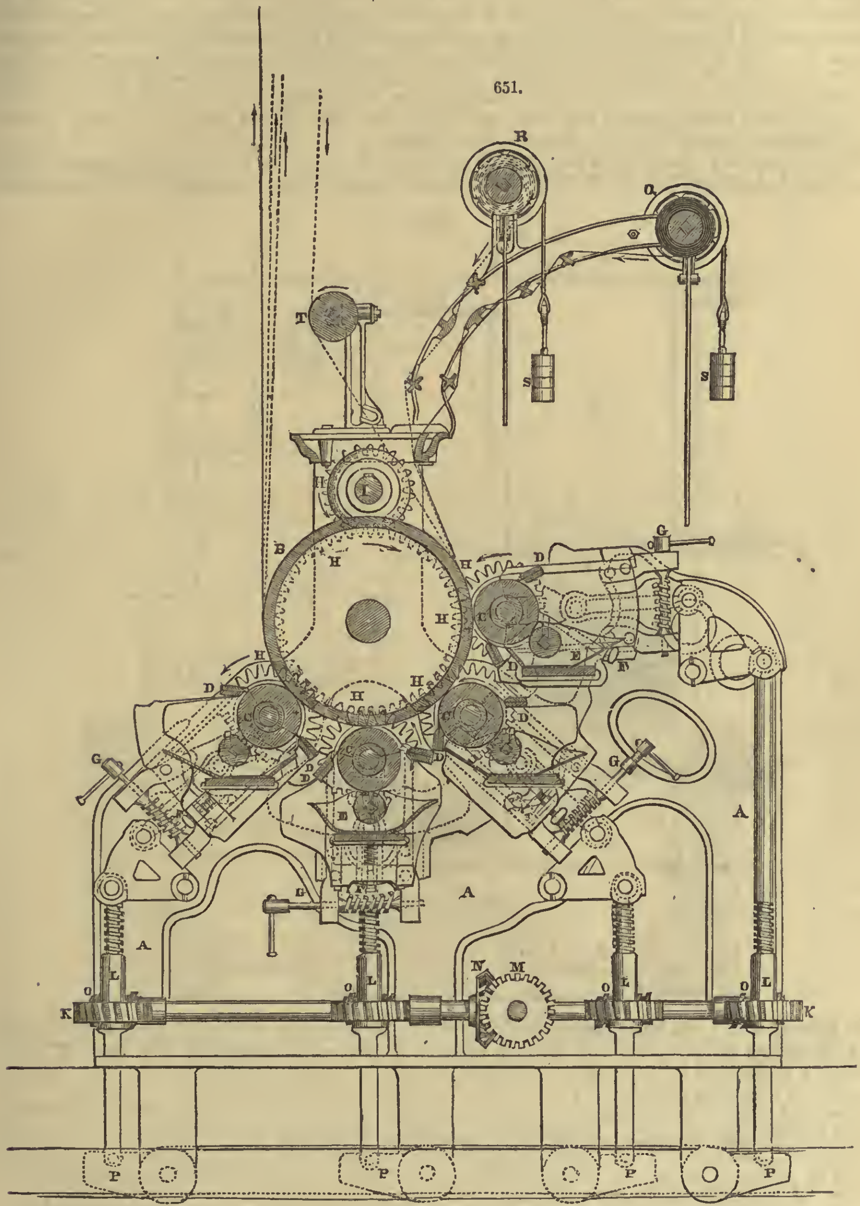
M. Huguenin thinks that a pressing-roller having only a diameter of 0·856 feet, for machines printing only one color, and that of those printing several colors, the smallest possible must be used. In some manufactures these rollers are wrapped with a band of a tissue, the warp of which is flax, and the weft of worsted, having the property of not lengthening under pressure; at the centre of the roller, this envelope is 0·062 feet thick, at the extremities 0·032 feet. The most modern improvement in this respect is the introduction of a tissue of cotton and caoutchouc.

The furnishing rollers have their circumference enveloped in a woollen cloth; their speed is inferior to that of the engraved cylinders; their diameter is generally about 0·328 feet.

The vessels in which the rollers dip are made of copper or wood. It is necessary to keep them sup

plied with a constant quantity of printing material, for the rollers would soon only skim over the surface of the fluid and leave but a feeble impression; to this end a reservoir pours a continual supply. A partition is placed in a position which enables it to clear the roller of the froth with which its surface may be covered.

651.

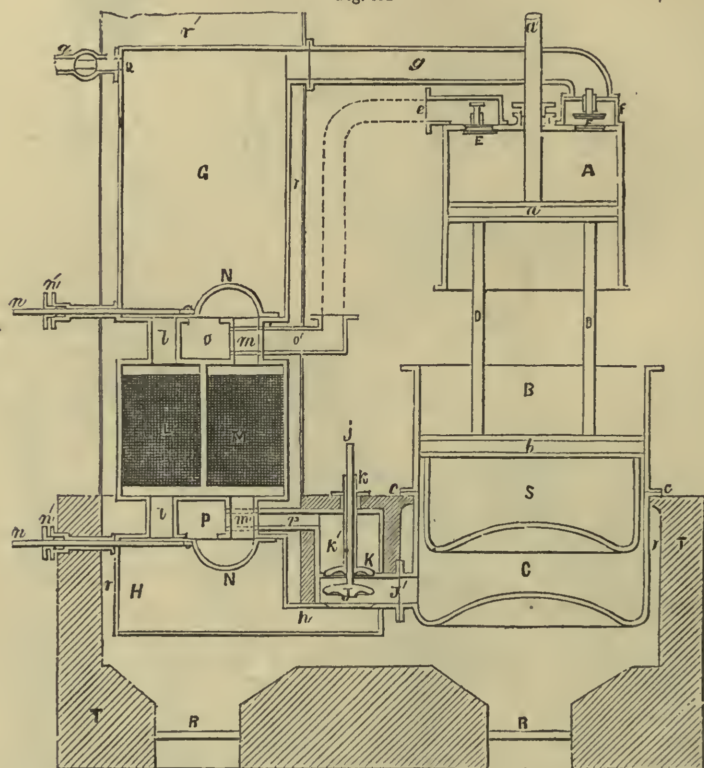


A A, frame-work.
B B B B, pressing cylinder.
C C C C, engraved cylinder.
D D D D, scrapers.
E E E E, vessels containing the coloring matter: they are raised and lowered at pleasure, by the screws F F F F.
G G G G, endless screw, guiding the regulators.
H H H H, pinions and wheels which turn all the machinery.
I, a shaft communicating with the moving power.
K K K K, wheels adapted to the female screws L L L L, which put the levers in communication with the pillows of the rollers.
M, a wheel communicating with the driving power, whose office is to press the rollers; it also moves the wheel N, and the endless screws O O O O, which are engaged with the wheels K K K K.
P P P P, levers which are loaded with weights in proportion with the pressure required: they are situated beneath the floor.
Q, the cylinder round which the cloth to be printed is rolled.
R, the cylinder round which the intermediate cloth is wound.
S, a weight which keeps the cloth stretched on the cylinders Q R.
T, a roller used to give an inclination to the cloth when printed, and regulate the speed

CALORIC ENGINE, *Ericsson's Patent.* The invention consists in producing motive power by the application of caloric to atmospheric air or other permanent gases or fluids susceptible of considerable expansion by the increase of temperature. The mode of applying the caloric being such, that after having caused the expansion or dilatation which produces the motive power, the caloric is transferred to certain metallic substances, and again retransferred from these substances to the acting medium at certain intervals, or at each successive stroke of the motive engine, the principal supply of caloric being thereby rendered independent of combustion or consumption of fuel; accordingly, whilst in the steam-engine the caloric is constantly wasted by being passed into the condenser, or by being carried off into the atmosphere, in the improved engine, the caloric is employed over and over again, thereby dispensing with the employment of combustibles, excepting for the purposes of restoring the heat lost by the expansion of the acting medium and that lost by radiation, also for the purpose of making good the small deficiency unavoidable in the transfer of the caloric.

We now proceed to describe the structure of the improved engine for producing motive power, reference being had to fig 652, A and B are two cylinders of unequal diameter, accurately bored and provided

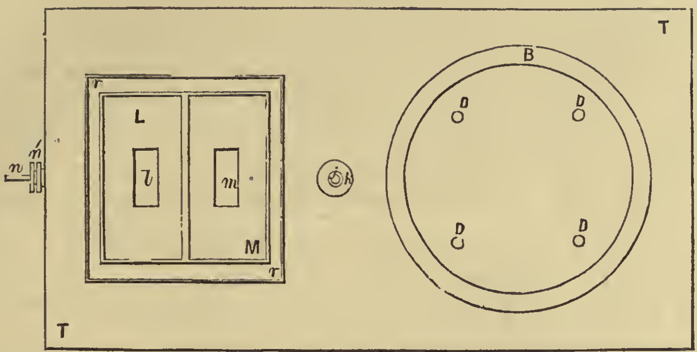
Fig. 652



with pistons *a* and *b*, the latter having air-tight metallic packing rings inserted at their circumferences. A is the supply cylinder, and B the working cylinder, *a'* piston-rod attached to the piston *a* working through a stuffing-box in the cover of the supply cylinder. C is a cylinder with a spherical bottom attached to the working cylinder at *c c;* this vessel is called the expansion heater. D D, rods or braces connecting together the supply piston *a*, and the working piston *b*. E is a self-acting valve opening inwards to the supply cylinder; F, a similar valve, opening outwards from said cylinder, and contained within the valve-box *f.* G is a cylindrical vessel, which is called the receiver, connected to the valve-box *f*, by means of the pipe *g.* H, a cylindrical vessel with an inverted spherical bottom, is called the heater. J, a conical valve supported by the valve stem *j*, and working in the valve-chamber J', which chamber also forms a communication between the expansion heater C and heater H, by means of the passage *h.* K is another conical valve, supported by the hollow valve-stem *k*, and contained within the valve chamber *k'*. L and M, two vessels of cubical form filled to their utmost capacity, excepting small spaces at top and bottom, with disks of wire net, or straight wires closely packed, or with other small metallic substances, or mineral substances, such as asbestos, so arranged as to have minute channels running up and down. These vessels, L and M, with their contents, are termed regenerators. *l l*, *m m*, pipes forming a direct communication between the receiver G, and the heater H, through the regenerators. N N, two ordinary slide-valves, arranged to form alternate communications between the pipes *l l* and *m m*, and the exhaust chambers, O and P, on the principle of the valves of ordinary high-pressure steam-engines; *n n*, valve-stems working through stuffing-boxes *n' n'*; *p*, pipe communicating between

the valve chamber k' and exhaust chamber P; o', pipe leading from exhaust chamber O; Q, pipe leading into the receiver G, provided with a stop-cock q. R R, fire-places for heating the vessels H and C; r r r r, flues leading from said fire-places, and terminating at r'. S, a cylindrical vessel attached to the working piston b, having a spherical bottom corresponding to the expansion vessel C. This vessel, S, which is the heat-intercepting vessel, is to be filled with fire-clay at the bottom, and ashes, charcoal, or other non-conducting substances towards the top, its object being to prevent any intense or injurious heat from reaching the working piston and cylinder. T T, brick-work or other fire-proof material surrounding the fire-places and heaters. Fig. 653 represents a sectional plan of fig. 1.

Fig 653.



Before describing the operation of the improved engine, it will be proper to observe that the piston-rod a' only receives and transmits the differential force of the piston b, viz., the excess of its acting force over the reacting force of piston a. This differential force imparted to said piston-rod may be communicated to machinery by any of the ordinary means, such as links, connecting-rods and cranks, or it may be transmitted directly for such purposes as pumping or blowing. The conical valves K and J may be worked by any of the ordinary means, such as eccentrics or cams, provided the means adopted be so arranged that the valve K will commence to open the instant that the piston b arrives at the full up-stroke, and be again closed the instant the piston arrives at full down-stroke, whilst the valve J is made to open at the same moment, and to close shortly before, or at the termination of the up-stroke. In like manner, the slide-valve N′ is to open and close as the piston b arrives respectively at its up and down stroke, similar to the slide-valve of an ordinary high-pressure engine.

Before starting the engine, fuel is put into the fire-places R R, and ignited, a slow combustion being kept up until the heaters and lower parts of the regenerators shall have been brought to a temperature of about 500°. By means of a hand-pump, or other simple means, atmospheric air is then forced into the receiver G through the pipe Q, until there is an internal pressure of some 8 or 10 pounds to the square inch. The valve J is then opened, as shown in the figure; the pressure entering under the piston b will cause the same to move upwards, and the air contained in A will be forced through the valve F into the receiver. The slide-valves N N being, by means of the two stems n n, previously so placed that the passages l l are open, the air from the receiver will pass through the wires in L into the heater H, and further into C, the temperature of the air augmenting, and its volume increasing as it passes through the heated wires and heaters. The smaller volume forced from A will, in consequence thereof, suffice to fill the larger space in C. Before the piston arrives at the top stroke, the valve J will be closed, and at the termination of the stroke the valve K will be opened; the pressure from below being thus removed, the piston will descend and the heated air in C will pass through k' p P and m into the regenerator M, and in its passage through the numerous small spaces or cells formed between the wires, part with the caloric, gradually falling in temperature until it passes off at o', nearly deprived of all its caloric. The commencement of the descent of the piston a will cause the valve F to close and the valve E to open, by which a fresh charge of atmospheric air is taken into the cylinder A. At the termination of the full down-stroke, the valve K is closed and the valve J again opened, and thus a continued reciprocating motion kept up. It will be evident that after a certain number of strokes the temperature of the wires or other matter contained in the regenerators will change; that of M will become gradually increased, and that of L diminished. The position of the side valves N N should, therefore, be reversed at the termination of every fifty strokes of the engine, more or less, which may be effected either by hand, or by a suitable connection to the engine. The position being, by either of these means, accordingly reversed to that represented in the drawing, the heated air or other medium passing off from C will now pass through the partially cooled wires in L, whilst the cold medium from the receiver will pass through the heated wires of M, and on entering H will have attained nearly the desired working temperature. In this manner the regenerators will alternately take up and give out caloric, whereby the circulating medium will principally become heated, independently of any combustion, after the engine shall have been once put in motion.

The relative diameter of the supply and working cylinder will depend on the expansibility of the acting medium employed; thus, in using atmospheric air or other permanent gases, the difference of the area of the pistons may be nearly as 2 to 1, whilst in using fluids, such as oils, which dilate but slightly, the difference of area should not much exceed one-tenth. In employing any other medium than atmospheric air, it becomes indispensable to connect the outlet pipe o' and the valve-box e of the

outlet valve E, as indicated by dotted lines in the drawing, these dotted lines representing the requisite connecting-pipe. The escaping air or fluid at o' will, when such a connecting-pipe has been applied, furnish the supply cylinder independently of other external communication, and the acting medium will perform a continuous circuit through the machine under this arrangement; the operation being in other respects as before described. The working cylinder may be placed horizontally or otherwise, and it may be made double acting; a heat-intercepting vessel may be applied at each end of the working piston, as also an expansion heater at each end of the working cylinder.

Stirling's Air Engine. Mr. Robert Stirling, a Presbyterian clergyman in Scotland, and an amateur in mechanical matters, made an engine the subject of a patent dated Oct. 1, 1840, which was described before the Institution of Civil Engineers, in 1846, by his brother, John Stirling. We present the description by Mr. S., as it appeared in the English mechanical magazines at the time. It will be seen that the Ericsson engine is but a slight advance on the engine of Stirling, the principal features being substantially the same in each: Stirling used the same air, as well as the same heat, over and over, while Ericsson takes fresh air every stroke. By the latter arrangement, cold air is obtained for the pump without taking trouble to cool the air of the exhaust for that purpose, but it involves the necessity of continually compressing a fresh quantity, a loss which can be but imperfectly compensated for by allowing the air to act expansively. Whether the gain or loss is greater in this arrangement has not yet been satisfactorily shown, either in theory or practice.

The principle upon which the movements of this air-engine depend, is the well-known one in pneumatics, that air has its bulk or pressure increased when its temperature is raised, and diminished when its temperature is lowered.

Two strong air-tight vessels are connected with the opposite ends of a cylinder, in which a piston works in the usual manner. About four-fifths of the interior space in these vessels is occupied by two similar air-tight vessels or plungers, which are suspended to the opposite extremities of a beam, and capable of being alternately moved up and down to the extent of the remaining fifth. By the motion of these interior vessels, which are filled with non-conducting substances, the air to be operated upon is moved from one end of the exterior vessels to the other, and as one end is kept at a high temperature, and the other as cold as possible, when the air is brought to the hot end, it becomes heated and has its pressure increased, and when it is brought to the cold end, its heat and pressure are diminished. Now, as the interior vessels necessarily move in opposite directions, it follows, that the pressure of the inclosed air in the one vessel is increased, while that of the other is diminished. A difference of pressure is thus produced upon the opposite sides of the piston, which is thereby made to move from the one end of the cylinder to the other, and by continually reversing the motion of the suspended bodies or plungers, the greater pressure is successively thrown upon a different side, and a reciprocating motion of the piston is kept up. The piston is connected with a fly-wheel in any of the usual modes, and the plungers, by whose motion the air is heated and cooled, are moved in the same manner, and nearly at the same relative time with the valves of a steam engine.

The power is greatly increased and made more economical by using somewhat highly-compressed air, which is at first introduced, and is afterwards maintained, by the continual action of an air-pump. The pump is employed in filling a separate magazine with compressed air, from which the engine can be at once charged to the working pressure.

If all the heat, however, which is necessary to raise the air to the required temperature, were to be thrown away or lost every time that the air is cooled, the power produced by its expansion and contraction would be much more expensive than that which is gained by the use of steam. In order, therefore, to understand how the work of a good steam-engine has been done, with about one-third of the fuel consumed by it, it is necessary to point out the method by which the greater part of the heat is preserved, and is used repeatedly, in expanding the air, before it is finally wasted or lost.

For this purpose, when it is necessary to cool the air, after it has been brought to its greatest heat, it is not at once brought into contact with the coldest part of the vessels. This would indeed effectually cool it, but the heat when thus extracted would be entirely lost, because it could never again be taken up by a body warmer than itself. Instead of this, therefore, the air is made to pass from the hot to the cold end of the air-vessel through a multitude of narrow passages, whose temperature is at first nearly as great as that of the hot air, but gradually declines till it becomes nearly as low as the coldest part of the air-vessel. Now, as every body by contact will give out heat to one that is colder than itself, the air, when it enters the narrow passages, must give out a portion of its heat, even to the hottest part of these passages, and must continue in its progress to give out more and more, as the temperature of the passages is diminished, till at last when it is ready to escape into the cold part of the vessel, there is only a small portion of the heat to be extracted, in order to bring it to the lowest temperature required. By far the greater part of the heat, therefore, has been left behind, in the metal which forms the passages, and which is so contrived and arranged, as to retain that heat until it is again required for heating the air. It must be evident also, from the manner in which the heat has been distributed, or spread out, over the whole length of those passages, that it is capable of being again employed in heating and expanding the air; for when the cold air is again made to enter the passages for the purpose of being heated, it immediately comes into contact with matter that is hotter than itself, and consequently begins to acquire heat, even at its first entrance; and as it is successively applied to surfaces of a greater temperature, it continues to receive more and more heat, so that when it comes at last to the hot end of the vessel, it requires but a small addition to its temperature to give it the elasticity which is necessary to move the piston. Thus, instead of being obliged to supply, at every stroke of the engine, as much heat as would be sufficient to raise the air from its lowest to its highest temperature, it is necessary to furnish only as much as will heat it the same number of degrees, by which the hottest part of the air-vessel exceeds the hottest part of the intermediate passages.

This arrangement or contrivance for the heating and cooling of air and other fluids, which may be

termed the economical process, forms the foundation of all the success which has been attained in producing power, with a small expenditure of fuel.

This principle was devised and acted upon by Mr. R. Stirling nearly thirty years ago, but until the present time it could not be said to have been beneficially applied to the production of power. The several means by which the principle is at last rendered effective, consist, chiefly, in the employment of various means for keeping the piston-rods air-tight, and enabling the pressure of the air to be raised to such an extent as to bring the engine into a small compass, and in the introduction of an effective refrigerating apparatus for extracting the waste heat and bringing the air to a lower temperature than could otherwise have been attained.

The greatest difficulty which was encountered, consisted in the proper application of the heat to the outside of the air-vessels. When applied directly by radiation from the fire to the spherical bottom of the vessels, it necessarily heated one part too much and another part too little, and the overheated part was not only liable to rapid oxidation, but by its expansion the other parts were strained and cracked. The heat is now applied chiefly by means of the hot-air which passes through the furnace; and it is found that, instead of requiring more fuel to keep up the heat, by this method it is accomplished with a considerable less quantity. It is found also that when the flues for distributing the heat over the surface are properly constructed, the air-vessels are very equally heated, and neither show a hurtful tendency to oxidation, nor to that unequal expansion by which the air-vessels might be destroyed.

The first engine of this kind which, after various modifications, was efficiently constructed and heated, had a cylinder of 12 inches in diameter, with a length of stroke of 2 feet, and made 40 strokes or revolutions in a minute. This engine moved all the machinery at the Dundee Foundry Company's works for eight or ten months, and was previously ascertained to be capable of raising 700,000 lbs. one foot in a minute. Finding this power to be too small for their works, the Dundee Foundry Company erected their present engine, with a cylinder of 16 inches in diameter, a stroke of 4 feet, and making 28 strokes in a minute. This engine has now been in continual operation for upwards of two years, and has not only performed the work of the foundry in the most satisfactory manner, but has been tested (by a friction brake on a third mover) to the extent of lifting nearly 1,500,000 lbs. It was found difficult to keep this load steadily applied for any length of time, owing to the strap becoming heated; but the engine has been worked for a whole day with a measured burden of 1,250,000 lbs., besides driving three extensive lines of shafting 370 feet in length; and this work is performed with an expenditure of 1000 lbs. of Scotch Chew coals, including the quantity necessary to raise the heat in the morning, and to maintain it during the two hours for meals, when the work was usually stopped. The coals used in this case were of inferior quality, and at least one-fourth less capable of producing heat than ordinary English coals. Taking this into account, and deducting 150 lbs., the quantity which was ascertained to be necessary for raising the heat in the morning, leaves a consumption of 600 lbs. in 12 hours. But little has yet been done in improving the furnaces, the principal attention having hitherto been devoted to ascertain the best method of heating the air-vessels, without regard to the economy of fuel. This result, although not so favorable as might be expected, is given to show the early capabilities of the engine. This engine requires only about a cubic inch of oil to keep the piston and the rod in order for two days, and in consequence of this, the friction of the cylinder and piston is decidedly less than it is in a steam-engine. In like manner the valves of the air-pump and safety-valves being free from moisture, do not show any tendency to get out of order. The leather collars are also very durable, that of the piston-rod usually lasting about three months, and the others six or nine months; and upon the whole, the working of the machine, besides the saving of fuel, is altogether more economical and less troublesome than that of a steam-engine.

It was perceived from the beginning, that in order to render the heating and cooling of the air complete and economical, it would be necessary to make the passages through which it is conveyed from one end of the air-vessels to the other, as narrow as possible. This is rendered necessary by the very defective conducting power of air, and the consequent difficulty of heating and cooling it. But on the other hand, the contraction of the passages, in which the air is heated and cooled, greatly increases the force which is necessary to pass it through them; so that, if they were made extremely narrow, the whole power of the engine might be consumed in transferring the air.

Mr. Stirling exhibited the model of the engine, and explained that the object was to raise the temperature of the air in the air-vessel, to such an extent as to obtain a difference of 500° between the heated and the cooled states. The air when heated might be taken at 650°, and after it had passed through the capillary passages, and the refrigerator, its temperature was 150°. The working pressure varied during each stroke from 160 lbs. to 240 lbs. per square inch.

CAM. If the axle of a wheel be situated in any other point than its centre, the wheel thus rendered *eccentric*, may produce by its revolution an alternate motion in any part exposed to its action. Circles, hearts, ellipses, parts of circles, and projecting parts of various forms, are made to produce alternate motion, by continually altering the distance of some movable part of the machine from the axis about which they revolve. Such projecting parts are called *cams*. See ECCENTRICS.

CAMBER. The convexity of a beam, frame or girder.

CAMERA OBSCURA. A converging object-glass adjusted to the shutter of a dark room, will concentrate the rays which come from external objects; and if these objects are very distant, compared with the focal distance of the glass, and situated nearly in the direction of its axis, it will give distinct images which may be received upon a white screen. These images are inverted; but in order to render them erect, it is sufficient to bring to the object-glass, instead of the direct light of the object, that of the image, already reflected and inverted by a metallic mirror. This apparatus is called a *camera obscura*. A plate of ground glass may be substituted for the screen, and for the room, a box fitted by means of a curtain to receive the head. It can then be transported with ease, for the purpose of landscape sketching.

Camera Lucida. If a quadrangular prism be cut in such a manner that the rays coming from neigh-

boring objects, and falling nearly perpendicularly upon its first surface, shall twice experience total reflection at its interior faces, and then, emerging perpendicularly through its last surface, arrive at the eye, an erect and horizontal image of the object, will appear to come through the prism. But if the pupil of the eye be so placed, that the rays thus reflected shall occupy only half of it, the other half jutting a little over the edge of the prism so as to admit the rays coming directly from a piece of pasteboard placed below; it is evident, that in this manner the spectator will see at once, with the same eye, the image and the screen upon which it appears to be thrown. If then he wishes to sketch the outlines with a fine pointed pencil, he will see at the same time the point of this pencil and the image, and there will be nothing to prevent his delineating it. This ingenious instrument was invented by Dr. Wollaston, and is frequently used by draughtsmen in copying details from Topographical Drawings.

CAMPHOR WOOD. See Woods, *varieties of.*

CAMWOODS. See Woods, *varieties of.*

CANALS. Canals are open channels of water for the purposes of navigation, water supply for cities and manufactories, for drainage, for irrigation, &c. The form and size of the canal will depend upon the purposes to which it is to be applied. For navigation, on the size of the boats and the amount of traffic. For water supply, drainage, &c., on the amount of water to be supplied or discharged.

The following Table is from Wm. J. Mc Alpine's Report to the N. Y. Legislature, in 1853.

NAME.	State.	Length in miles.	Cost.	Cost per mile.	Width at surface. Feet.	Depth of water. Feet.	Locks.				Burthen of boats. Tons.
							Length. Feet.	Width. Feet.	Number.	Lift. Feet.	
Erie,	New York,	363	$7,143,789	$19,679	40	4	90	15	84	...	80
Champlain,	do	63	1,257,604	19,962	..	..	100	..	19	194	...
Oswego,	do	38	525,115	13,818	..	...	90	..	24	238	...
Cayuga and Seneca,	do	21	236,985	11,285	..	..	..	..	12	73	...
Chemung,	do	23	648,600	28,200	..	..	..	..	54	516	...
Crooked Lake,	do	8	156,776	19,597	..	..	..	..	28	280	...
Chenango,	do	97	2,419,956	24,948	..	..	..	..	117	1,009	...
Total,	do	513	$12,388,915	$24,150							
Central Division,	Penn., public,	173	$5,307,252	$30,677	40	4	90	15	110	671	80
Western do	do	104	3,096,522	......	..	..	..	..	70	471	...
Susquehanna Division,	do	39	1,039,256	26,647	..	..	..	..	12	86½	...
North Branch,	do	73	1,096,178	15,016	..	..	..	..	8	69	...
North Branch Exten.,	do	90	3,528,302	39,203	..	..	90	15	29	189½	80
West Branch,	do	73	927,388	12,703	..	..	..	..	19	138½	...
Delaware Division,	do	60	1,275,715	21,261	40	5	90	11	23	164	...
Beaver do	do	31	512,360	16,662	..	..	..	..	17	132	...
Total,	do	643	$16,782,973	$26,100							
Schuylkill,	Penn., private.,	108	$2,500,176	$23,149	36	3½	80	17	120	610	...
Lehigh,	do	85	4,455,099	51,208	60	5	100	20	81	1,289	100
			$6,955,275	$36,000							
Union,	Penn.,	82	....	......	36	4	75	8½	95	519	...
Delaware and Hudson,	N. Y. and Penn.,	108	$2,500,000	$23,150	32	4	76	9	107	950	50
do enlarged,	do	108	6,500,000	60,200	44	6	100	15			140
Del. & Raritan & feeder,	New Jersey,	43	$2,844,103	$66,150	75	7	110	24	18	116	228
Morris and Essex,	do	101	3,100,000	30,693	32	4	..	..	29 locks 22 planes	1,674	...
Total,	....	144	$5,944,103	$41,300							
Chesapeake and Del.,	Del. and Md.,	13½	$2,750,000	$203,703	66	10	100	22	4	...	...
Chesapeake and Ohio,	do	191	10,000,000	52,356	70	6	..	..	....	600	150
Total,	....	204½	$12,750,000	$62,350							
Ohio and Erie,	Ohio,	307	$4,695,824	$15,300	40	4	90	15	152	1,185	...
Miami,	do	178	3,750,000	21,067	..	..	..	..	102	781	...
Mahoning,	do	85	764,372	8,992	..	..	..	..	....	...	...
Sandy and Beaver,	do	76	1,500,000	19,722	..	..	90	15	....	...	80
Total,	....	646	$10,710,196	$16,600							
James R. and Kanawha,	Virginia,	147	$5,020,050	$34,150	40	4	100	15	.. ..	1,916	...
Wabash and Erie.	Indiana,	379	....	......	60	4					
do	do	90	$3,057,120	$33.968	45	3					
Ill. and Michigan,	Illinois,	102	$8,654,337	$84,846	60	6	..	..	2	20	150
Welland,	Canada,	36	$7,000,000	$194,444	71	10	150	26½	27	846	500
St. Lawrence,	do	10	1,000,000	100,000	90	10	200	45	6	30	...
Cornwall,	do	12	2,000,000	166,666	150	10	200	55	7	48	...
Beauharnois,	do	11	1,500,000	136,363	190	10	200	45	9	82	...
Lachine,	do	8½	2,000,000	235,934	120	10	200	55	5	45	...
Chambly,	do	12	400,000	33,333	60	8	120	24	9	74	...
Total,	....	89½	$13,900,000	$155,300							

For the enlargement of the Erie canal, the following dimensions have been adopted:—Width at water-line, 70 feet. Width at bottom, 28 feet. Depth of water, 7 feet. Width of tow-path, 14 feet.

The Caledonian canal in Scotland is remarkable for its size, which will admit of the passage of frigates of the second class. Its principal dimensions are as follows:—Width at water-line, 100 feet. At bottom, 50 feet. Depth of water, 20 feet. Length of locks between mitresills, 180 feet. Width of chamber at top, 40 feet. Lift of lock, 8 feet.

Crossection. In canals of this country the interior slopes are generally uniform, from $1\frac{1}{4}$ to $1\frac{1}{2}$ horizontal, to 1 perpendicular, the slopes being paved or rubbled near the top, to prevent the wash. The tow-paths are about two feet above the level of the water, and from 6 to 12 feet wide. The path should slope outwards from the canal so that the surface water and earth may not be carried into the channel. With regard to the supply of water necessary for a canal, or for a level of canal, it embraces the quantity required for the service of the navigation, that is, the number of times the chambers of the locks will require to be used in the passage of boats, and the losses arising from evaporation, from leakage through the soil and through the lock gates, the necessary first fillings of the levels and the chance of accidents or breaches, and the emptying of the levels for repairs. In estimating the quantity expended for the service of navigation the problem is simple, knowing the capacity, form and number of locks, the size of boats and the contemplated amount of traffic. With regard to the other losses it must be a great deal a matter of conjecture. From experiments made by Mr. J. B. Jervis on the Erie canal, the total loss from evaporation, filtration, and leakage through the gates, is about 100 cubic feet per minute for each mile. Having determined the amount of water required, the source of the supply must be guaged, and if the minimum flow of the stream be not sufficient, reservoirs must be constructed to equalize the supply. For the forms and dimension of locks, see "Locks of Canals."

On the cost of transportation on canals, we again extract from the able Report of Mr. Mc Alpine.

The cost of transportation of coal in 1848 on the Chesapeake and Ohio canal from Cumberland to Georgetown, a distance of 184.4 miles, was \$78.06, or $4\frac{1}{4}$ mills per ton per mile, including the interest on the cost of the boats and fixtures, annual repairs and depreciation on the same, cost of towing, wages of men, cost of loading and unloading.

The cost of transportation of coal on the Schuylkill canal is \$44.54 for 108 miles, or $4\frac{1}{10}$ mills per ton per mile; the cost on the Delaware and Hudson canal is about the same.

The cost of all expenses of running, towing, and decrease of value of horses, office and personal expenses, and part cost of loading and unloading on the Erie canal in 1852, was $2\frac{9}{10}$ mills per ton per mile. Mr. Seymour, the late State engineer, estimated the whole cost at $3\frac{1}{2}$ mills per ton per mile. The charges for transportation on the Erie canal in 1851 and 1852 (except late in the season) have averaged \$2.50 per ton for down, and \$2.35 per ton for up freight (exclusive of the charge for State tolls), being at the rate of 6.9 and 6.5 mills per ton per mile.

The charges for transportation of coal on the Schuylkill canal in 1852, was \$0.65 for 108 miles, or 6 mills per ton per mile; and on the Delaware and Hudson canal, about $5\frac{1}{2}$ mills per ton per mile. On the latter canal they have ascertained that the cost of transportation has been reduced more than forty per cent. by enlarging the canal from a capacity for boats of 50 tons to that of 115 tons.

In 1848, the Delaware and Hudson Canal Company determined to enlarge the dimensions of their canal for the purpose of accommodating the increased amount of trade, and to cheapen the cost of transportation. This has been accomplished at an expense of about $2\frac{1}{2}$ millions of dollars.

The engineer of that work, R. F. Lord, Esq., prepared very careful estimates of the saving in the cost of transportation which the enlargement would effect, as follows: "The charge for freight on the old canal which was competent for boats of 50 tons, was \$1 per ton for 108 miles, or nearly one cent per ton per mile. The estimated charge for freighting with the canal enlarged for boats of the following tonnages, was:

"For 100 tons, 65 cents, equal to $5\frac{6}{10}$ mills per ton per mile.
116 tons, 58 cents, equal to $5\frac{4}{10}$ mills per ton per mile.
136 tons, 50 cents, equal to $4\frac{6}{10}$ mills per ton per mile.

The company determined to enlarge the canal to the last mentioned capacity, which has been done, and boats now carry from 115 to 141 tons, at a saving in the cost of transportation equal to that estimated.

Canals for the supply of water to cities or to manufactories, are generally walled at the sides, and are deeper in proportion to their width than those used for the purposes of navigation. The area of their section is to be proportioned to the quantity to be supplied. The mean velocity is usually from 1 to 2 feet per second. The greater the velocity the more the inclination of the surface and the consequent loss of head and fall. It becomes then a matter of calculation, how much may be saved by the first investment by the construction of a canal of small area, and a consequent continual loss of available power. For the rules for calculating the flow of water in canals, see Hydraulics.

The velocity of the water in a water-course should be neither too slow, for then the course chokes with weeds, nor too fast, for then the bed of the channel may be disturbed, and besides, too much fall must not be lost in the inclination of the course.

A velocity of 7 to 8 inches per second is necessary to prevent deposit of slime and growth of weeds, and $1\frac{1}{4}$ feet per second is necessary to prevent deposit of sand. The maximum velocity of water in canals depends on the nature of the channels' bed.

On a slimy bed the velocity should not exceed $\frac{1}{4}$ f't,	On a shingle bed the velocity should not exceed 4 f't
" clay " " . . . $\frac{1}{2}$ "	" conglomerate " " . . . 5 "
" sandy " " . . . 1 "	" hard stone " " . . . 10 "
" gravelly " " . . . 2 "	This applies to the mean velocity.

The water-courses for water-wheels and general uses of the Freyberg mining district have inclinations varying from 15 inches to 30 inches per mile. The New River which supplies a great part of London, has an inclination of $\frac{470}{1000}$ per mile.

CANARY-WOOD. See WOODS, *varieties of.*
CANGICA WOOD. See WOODS, *varieties of.*

CANDLES, *Wax.* Next to tallow, the substance most employed in the manufacture of candles is wax. Wax candles are made either by the hand or with a ladle. In the former case, the wax being kept soft in hot water, is applied bit by bit to the wick, which is hung from a hook in the wall; in the latter, the wicks are hung round an iron circle, placed immediately over a large copper-tinned basin full of melted wax, which is poured upon their tops, one after another, by means of a large ladle. When the candles have, by either process, acquired the proper size, they are taken from the hooks, and rolled upon a table, usually of walnut-tree, with a long square instrument of box, smooth at the bottom.

CANDLES, *Stearic—Manufacture of.* Among the tallows which are best adapted for the preparation of stearic candles, are those of beef and mutton. All other fatty matter is poor in solid acid, or of too considerable a price. It is, then, the quantity of acid, stearic or margaric, which is found in a given weight of beef or mutton, and the facility in working the same, which ought to determine in giving preference to this or that quality of tallow. The mutton tallow contains the greater quantity of solid acid, and is the more easily worked. That of beef is, generally speaking, to be procured a little cheaper.

The manufacturers of stearic candles, to free themselves from the inconvenience of melting, are generally in the habit of buying from the butchers fat already melted. This method is far from being the best, as it is almost impossible to judge the purity of the tallow when it has been melted, and at the same time gives an opening for imposition to a considerable extent. Thus it would be most important to the manufacturer to purchase the tallow in lumps, in such manner as it is taken from the animal, covered with its membranes, and bound in its cellular tissue, and to melt it himself.

This operation of melting is performed in the slaughter-houses of Paris in a very simple manner. They have a great copper, from 6·56 feet to 7·21 feet diameter, and from 3·28 feet to 3.93 feet in depth, swelling at the bottom as in a stewpan, and widening at the top, so as to be enabled to rest upon a circular oven. This is constructed in such manner that the hearth, of a breadth of 1·32 feet, is exactly under the copper, from its circumference to its centre. The flame and hot air heat at first the whole of the bottom surface, and then circulate twice round the cylindrical part of the copper before passing up the chimney. They throw the fat in this copper by an inclined plane, which proceeds from the upper story, and during the melting they stir it with a long rod. When they have reached a proper degree of fusion, which is generally obtained in about four or six hours, according to the nature of the fat, they turn it out, first into a large iron-plate reservoir, of the same size as the copper, and which is furnished with two cocks, from which it is drawn off into slightly conical vessels, so as to form large lumps of a conical shape.

It is well to place under the copper a large funnel, the same as in a forge, to conduct the gas which escapes from the fat during the operation to the chimney. There should be also in the same factory a screw-press, for compressing the membranous part, in order that no portion of fat may be lost.

The different operations in general use for the manufacture of such candles are generally divided as follows:

1st. The formation of soap; the object of which is to combine the acidulated fat with the lime, to produce the glycerine, and obtain the stearate, margarate, and oleate of lime. The glycerine dissolves itself in the water necessary for this preparation.

2d. The pulverizing of the lime soaps.

3d. The decomposition of these same soaps by sulphuric acid diluted with water.

4th. The cleansing of these stearic, margaric, and oleic acids—first, by water slightly acidulated, and secondly, by pure water.

5th. The moulding and crystallization of the now obtained acid fats.

6th. The melting of the crystalline masses into small layers instead of large rolls.

7th. The cold-pressure of the acids thus formed into layers.

8th. The hot-pressure of these layers now reduced.

9th. The purification of the solid acids by water slightly acidulated at first, and secondly by pure water.

10th. The melting and moulding of the solid acids into moulds; then the clipping of the candles.

11th. The bleaching of the candles.

12th. The polishing, packing, &c., for removal.

Description of the Machinery.—Fig. 652 represents the general plan of a manufactory, indicating the utensils which are employed.

Fig. 653 is a sectional view of this manufactory, vertically and longitudinally; and the figures 654, 655, 656, and 657, represent in elevation, or sectionally, the details of the principal utensils, and the means of communicating the movement.

The Formation of Soap.—This operation is performed in a large vat, generally constructed of wood, slightly conical in form, and provided with several frets all the way up. The bottom and the lid are of wood, and its capacity is sufficiently great to contain, easily, more than 70·58 cubic feet. They generally place about 1100 lbs. of tallow, with a proportion of water rather more than enough to easily dissolve the same, and which would be about 200 gallons. This is heated by steam from a leaden pipe *g*, winding in a serpentine manner, and placed at the bottom of this trough. This pipe is perforated with a number of small holes, across which the steam passes as it proceeds from the coppers A or A′, with which it is in communication. When this is melted, they add, by degrees, 165 lbs. of lime well mixed; and they allow this preparation time to mingle, taking, at the same time, great care to stir it by means of an agitator *p*, composed of many branches united by a cross-piece, and having a

kind of knife fixed at each of the four arms. This contrivance is mounted upon a vertical beam o to which is given a rotary movement by the wheel n fixed to the upper part of the beam.

This wheel is acted upon by a pinion n' adjusted upon the horizontal beam, which communicates with the prime mover by the two pair of cog-wheels $l\,l'$ and $j\,j'$, mounted on one part upon the vertical beam k, and on the other part upon the horizontal beam F, as seen in Figs. 652 and 653. An energetic stirring is most important, because it more fully completes the formation of soap, and economizes, consequently, the sulphuric acid.

Generally, in the greater part of the manufactories, says Mons. Dumas, they use, perhaps, 33 lbs., and sometimes more, of sulphuric acid, to the 220 lbs. of tallow, while they ought only to use from 19 to 22 lbs. to 220 lbs. of tallow. It is often, then, a third too much, and an experienced manufacturer would do well to pay attention to this.

They had proposed to give the movement to this agitator by means of a cord, but they found they were obliged to give up this, as they could not obtain a regular movement—during one part of the operation the matter, being very compact, would present a great resistance, and the rope would give.

The time for the formation of soap is generally from 6 to 8 hours. At the end of this period they draw off, by means of a tap q' placed in the bottom of the trough, the liquid part which has absorbed the glycerine, and they take from the trough all the solid which remains there, which is now a formation of stearate, margarate, and oleate of lime, in the form of a very hard soap; this they throw upon the floor, upon which rests the trough J.

Pulverizing.—To pulverize the soap, they use, in many manufactories, a roller of cast-iron K, which they pass to and fro in an alternate movement, and generally by manual labor. Mons. Dumas proposes to have the soap pass between two cylinders moistened by a stream of cold water, which should bathe it; a precaution most indispensable, because the soap, heated by the pressure, would soften, and render itself more often in cakes than in powder.

Troughs for Decomposition.—The two troughs J^1 and J^2, into which is conveyed the solid matter after it has been broken, are designed for the decomposition of these matters by the action of sulphuric acid much diluted with water. Like the former, in shape they are slightly conical, and nearly of the same dimensions, heated by steam by a serpentine pipe q'. They ought, also, as with the former troughs for the formation of soap, to be cased with lead, so as to be protected from the action of the sulphuric acid. It would be quite as well to fit up both with a mechanical agitator, though in many manufactories they are not so. These troughs are generally on a lower floor, under the trough for the formation of soap, so that they can easily dispose of the matter.

The quantity of sulphuric acid necessary for the decomposition of these lime soaps can be easily determined. For 1100 lbs. of tallow, according to Mons. Dumas, they would use 165 lbs. of lime; or for 220 lbs. of lime the equivalent in sulphuric acid is equal to 36·7 lbs., at 66° centigrade. Consequently, for 165 lbs. of lime will be necessary 275 lbs. of this acid. In practice they add from 10 to 15 per cent. to this quantity, and the acid being, we suppose, at 66°, they dilute it by twenty times its quantity of water. At the end of about three hours the decomposition of these soaps is effected. They then displace the mass. The fat acid comes to the surface, and the sulphate of lime is precipitated to the bottom.

Cleansing the Acids.—For this purpose they withdraw, by means of a tap q', which is placed underneath, and which, like the preceding ones, is cased in lead, and equally heated by steam by a serpentine pipe placed in the bottom. It is as well to have a second trough L, similar to the preceding one, to complete the cleansing, in which they work only with pure water. The passages R, inserted in the interior of the roof, serve to establish a communication with the two troughs of decomposition J J′, and with those of cleansing L L′, and to carry the liquid off or into the lower reservoirs. As much as possible of sulphuric acid and lime are drawn off into a series of zinc moulds M, which are arranged in rows along the entire length of the workshop, in such manner, that in drawing it off into the first mould it flows gently into the adjoining moulds, which is easily done by attaching to each brim of the moulds a gutter, which carries off the superfluous matter at its proper height.

These moulds present the form of a rectangular prism from 27 to 39 inches in length, from 6¼ to 7 inches in breadth, and about 16½ feet only in height. Thus are formed layers of solidified acid, which are taken away (after being wrapped in woollen serge) to the vertical hydraulic press N, which is constructed exactly similar to the ordinary presses, of which it is easy to see the construction by reference to the design, Fig. 653, where it is shown in vertical section.

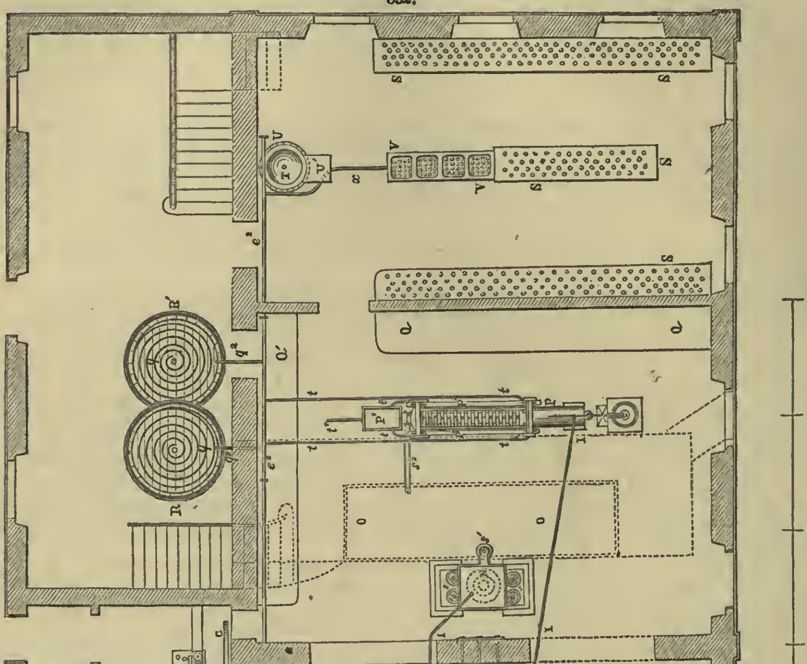
The drawing off into these moulds, such as we have endeavored to show, is only a modern application. Previously the acids were drawn off into larger moulds, which could contain about 7 gallons, and which were a little wider at the top, so that the matter could be the more easily extracted. These rolls were broken into smaller pieces by the action of a knife with an alternate movement, similar to a knife for cutting straw into small parts. Since the use of these newly-invented moulds, they economize nearly one-horse power in the impelling force.

Cold Pressure.—The vertical hydraulic press ought to be constructed to obtain a pressure of 440,000 lbs. A great part of the oleic acid flows cool to the action of this press, but, however, the latter portions can only be extracted by the aid of a certain temperature. Other presses of horizontal construction, and which are heated by steam, are employed. Such is the press represented in P P′, upon the plan, Fig. 652, and upon the vertical section, Fig. 653.

Hot Pressure.—This press is heated; also the wrought-iron plates P^3, between which are placed the links which proceed from the vertical press, and which, in issuing from this press, are enveloped in horse-hair material, in place of woollen serge.

On the opposite side to the piston of the press is a cast-iron rectangular chest P^2, airtight, in which is enclosed a similar action of plates. The steam proceeding from the generators A or A′, passes by the pipes e, e^1, e^2, t, finds its way into the double sides, as also into the double bottom of the press, to heat it. It afterwards passes by the pipes t', which carry it into the chest P^2, where there is a full

652.



action of plates P^3 to be employed as soon as the press will have ceased to work, and where they may take away those that they have used. They can still heat these plates by boiling water in a trough, also in cast-iron. It is shown by Fig. 653 in what manner these plates can be raised to furnish heat to the press, or reciprocally.

They have provided for this purpose, in the upper part of each of them, an eye, which permits the introduction of a hook fixed to the extremity of the cord u, which passes into a throat of cast-iron to the pulley. The upper part of the locket of this pulley ends with an elongated eye, to enable it to glide easily the entire length of an iron way fixed to the plank, and below the press, lengthwise—so that one of the plates being raised, they can advance the locket in a perpendicular line. They can transport them in succession either from the press to the chest, (which serves as a heater,) or from the chest to the press.

The pressure of the piston of the press often ranges from 880,000 lbs. to 1,100,000. Some, after a certain time of working, have had the bottom of the cylinder carried away by the pressure; and, in certain factories, others have been destroyed by the rupture of the long braces, which connect the heads of these presses, and which were not sufficiently strong in themselves.

The oleic acid which flows from the vertical press, or from the horizontal one, into a lower receptacle O, by the pipes S^1 S^2, from which it is drawn for the receiver into the flat vessels, by the cooling, deposites the stearic acid that it had absorbed in consequence of the increased temperature which it underwent during the action of the horizontal press.

The two pressures completed, the oleic acid is regarded as sufficiently separated, and the residual matter, formed by the stearic and margaric acids, is of brilliant whiteness; they only equal about 45 to 50 per cent. of the tallow employed.

The injecting-pumps are shown by H and H, Figs. 652 and 653, which clear the two horizontal and vertical presses. They are put into action by the horizontal beam F, which communicates with the impelling power, which is an engine of about 4-horse power—a power more than sufficient to put in motion the necessary apparatus of this manufactory.

Upon the horizontal beam E is a cast-iron upright wheel f, which commands the wheel f^1, fixed upon the horizontal beam g. This has, at its extremity, two small winches, which, by the accession of two rods h, impart to the pistons of the injection-pumps i i^1 the movement for casting the water that they draw into the great bodies of the presses N, P^1. The heads of the vertical press are supported at a convenient distance by four cast-iron columns, interlaced by large iron bolts all the way up, and the liquid matter falls upon the lower plate, which unites with the piston, and upon which they have adjusted a small trench or gutter, to allow it to flow by the pipe s^1, finished in its upper part in form of a funnel, and which conducts it into the reservoir O.

Purification of the Solid Acids.—The lumps of stearic and margaric acids which are taken from the horizontal press, are carried to the trough R, to be there purified by dilute sulphuric acid.

This trough is constructed exactly similar to the preceding—cased in lead, and heated by steam, by the pipe q^2, which conducts the same in the serpentine q, which liquefies the acids. It must be understood that this cleansing has for its object to disengage the fat acids from the remotest trace of lime that they may contain. After this operation, it only remains to free them also from the acid itself, by purifying with water. They then allow this to remain, or decant it into another trough R^1, situated upon a lower floor, and which only contains pure water, and which should be occasionally replenished. They then allow it to cool, draw it off into moulds, and at length is obtained rolls perfectly fit for working into candles.

Melting and Moulding the White Solid Acids.—They use for this purpose a copper, T, (see Figs. 652, 654, 655,) which are in the interior silver-plated, to prevent the discoloration of the acids. This copper is double-bottomed, to be heated by steam at a temperature which should not ordinarily exceed 100 degrees.

The steam proceeds from the generators into the double bottom by the pipe v, and this, condensed flows off by a pipe v^1. A tap v^2, attached to the pipe which issues from the bottom of the copper, serves to empty it completely. It is surrounded by a coat of wooden staves U, to prevent the cooling of the trough. By the side of this copper they have placed a table V, upon which rests the vessel T^1, which serves to receive the melted matter to be carried into the moulds.

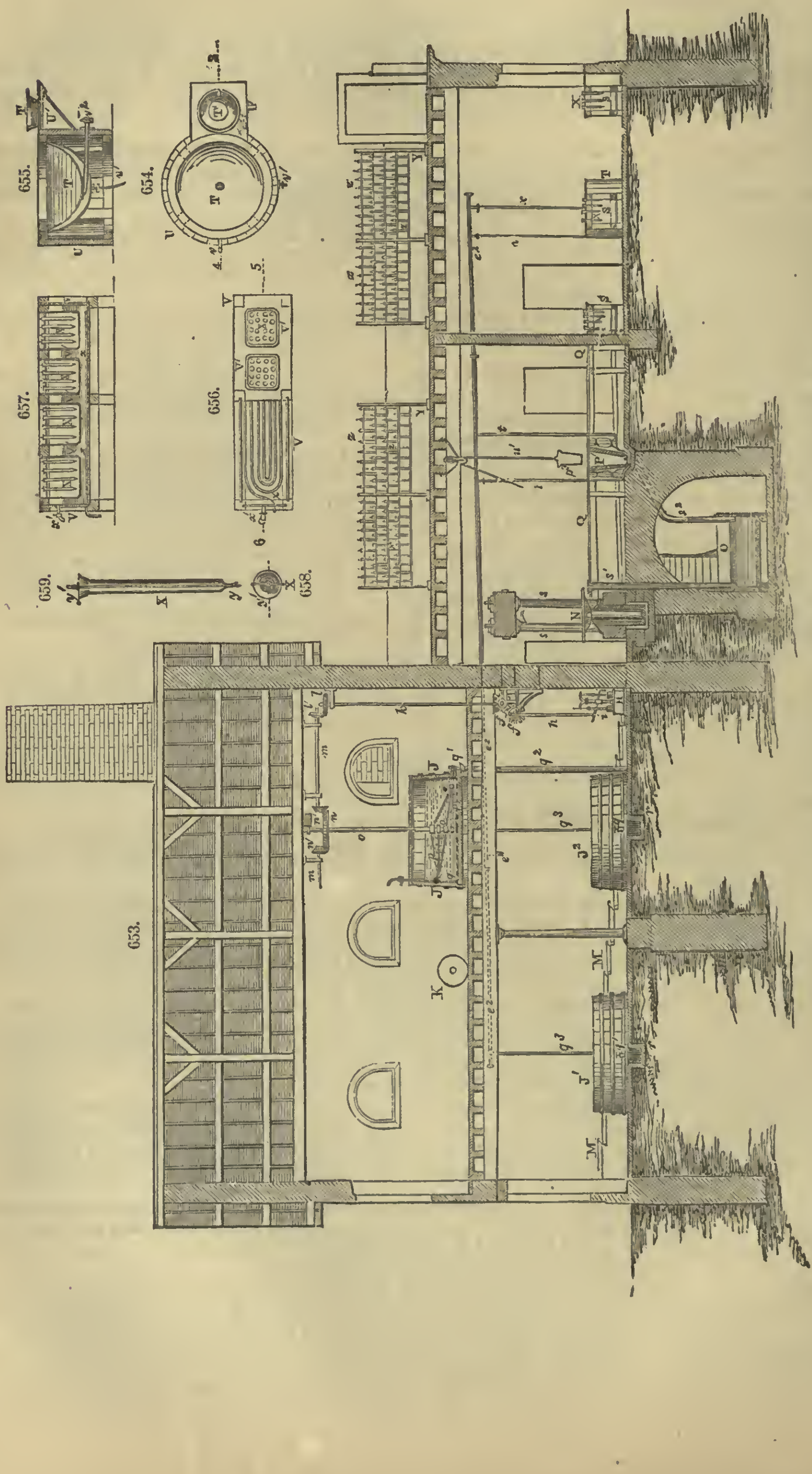
In order to make the candles and the stalactites which form upon them less powdery, they generally add 10 per cent. of sulphuric acid, when they throw in this copper the rolls of stearine. They cool these candles in moulds similar to those represented in plan and in section, Figs. 658 and 659. These moulds are formed of an alloy, composed of one-third pewter and two-thirds lead. It will be perceived that they are slightly conical, and terminated by a kind of funnel.

They fix the wick to the upper part by a bent pin y^1, and to the lower by a little wooden peg y, which closes against the sides of the orifice. These wicks are matted, which prevents the necessity of constantly snuffing the candles; for this purpose, says Mons. Dumas, it will be necessary to dip them in a solution of borax, which forms with the lime a borate which fixes itself in the wick, and serves to consume it.

To fix the wicks, the moulds are placed vertically in the holes of the wooden tables S, conveniently arranged in the workshop, and upon which they allow the candles to cool, after they are drawn off. For this purpose, after the wicks are fixed in the centre of the moulds, they carry them to the hot-water basins, which are brought up to the temperature of boiling water.

This system of heating is brought about by several basins V, represented in plan and section, (see Figs. 656, 657, and 652.) They are entirely surrounded by water, heated by a current of steam coming from the generators by the pipe x in the serpentine x^1, placed in the bottom of the apparatus.

When the moulds are sufficiently hot, they are filled by the aid of a small vessel T^1, which they plunge in the copper T. It should be first ascertained that the acid has commenced to crystallize. This precaution, as much as that of heating the moulds, is very essential to neutralize the crystalli-



653. 654. 655. 656. 657. 658. 659.

Fig. 653: Scale.—5 inches = 33 feet. Figs. 654 to 659: Scale.—8 inches = 13 feet.

zation of the fat acids—a crystallization which would give to the candles a very disagreeable appearance.

After the cooling of the moulds, they remove the small wooden peg which holds the wick, and by means of a punch, they extract the candle. The roll must also be cut, and the candles be put lengthwise. For this purpose many mechanical means have been tried, and which have not produced very satisfactory results; the difficulty to avoid breaking the candle being so great. However, they are at this moment trying the effect of a certain mechanical knife or circular saw, from which much is expected. For this process we believe it is most important that the cutting-blade should possess great rapidity and very little pressure.

Bleaching the Candles.—When the candles are moulded, they should be exposed for some time to the air, to the light, and to a humid atmosphere, that they may possess as white an appearance as possible. This is generally done upon the roof of the workshop itself, which should be constructed in the form of a terrace, where the candles *z* can be arranged upon the trays Y. Space should be economized as much as possible.

Polishing the Candles.—The last two processes which the candles have to undergo, after they have been exposed to the air some time, are the polishing and the packing. The polishing is done by rubbing the candle briskly with a piece of cloth, damped with alcohol or ammonia; and this is generally done by women or children. They have also tried to produce the polish by a mechanical process, having a kind of cylindrical plug or bung of wool or cloth, to which was imparted a regular to-and-fro movement, whilst the candles were immediately placed under the same, and by the means of endless chains, which advanced gradually upon a horizontal table, the candles rested and turned equally at the same time. This process is the invention of a Mons. Davison, of Paris, who has taken a patent out for it for five years. The packing consists in arranging them to form packets of one pound, and they are carefully and neatly secured ready for use.

Boilers, or Steam-coppers of the Machine.—The two boilers A and A′, represented in Fig. 652, are for the purpose of feeding not only the engine, (of 4-horse power,) but also for heating the different troughs; for the formation of soap; for decomposition and cleansing the horizontal press; the copper for melting, and the warmer. These boilers are of 16-horse power. There are some factories which have them as large as 20-horse power. Fig. 652 represents a horizontal projection seen from the top, and shows the disposition of these boilers, with their safety-valves, and also the pipes for conducting steam. In B will be perceived the brick furnace, in which the boilers are imbedded; in *b* the safety-valves; and in *b′* the floats: *c* shows the pipe communications with alimentary pump; *e′ e′* the pipes for conducting the steam to the different apparatus of the machine; and *d d′* the pipes which furnish the steam-engine. All these pipes are of copper, and provided with taps.

Application of the Oleic Acid.—This acid, for a long time in the different factories for the manufacture of stearic candles, was regarded as a superfluous residue, and you may say completely lost, with respect to any advantage that could be derived from it. Messrs. Pelicot & Alcan have been successful in applying it to the purpose of greasing the wool employed in silk-yarn manufactories, or in scouring it.

It is well known, in the picking or combing of wool, that a nap as homogeneous as possible is necessary. It is first prepared with a certain quantity of fat matter. This preparation is so far necessary, that without it the twisting and stretching of the wool would only be accomplished indifferently, and the loss would be greater. The thread thus obtained would be more unequal, and would not possess, for weaving, the quality required for the production of stuffs. Until within the last few years they have employed, for this purpose, vegetable oils, in most of the principal factories at Rheims, Sedan, Elbeuf, &c. In the factories of the south, olive oil was almost always used, whilst in the suburbs of Paris they have given the preference to the oil from grains, which was cheaper, and in some cases a mixture of water and oil is used, brought to a state of emulsion by the addition of a small quantity of potass.

The oil with which wool is impregnated should only remain until immediately after the spinning or weaving. Scouring should commence at that period. The process of scouring varies with the nature of the stuff they propose to manufacture. For cloths and felt stuffs it is done after the weaving, and before fulling. For light and rasé stuffs it is generally done upon the thread, and before the weaving.

At Elbeuf, Louviers, and other places, scouring is accomplished by means of potters' clay saturated with water. The thread being impregnated with this substance, they pass it between two compressing cylinders, which brings it in contact with the greasy matter; this is consequently displaced, mechanically, and is drawn off by the water, which flows in great quantities. This process will take from eight to twelve hours, and it will affect the soundness and color of the tissue; besides, the accidental presence of any small stone in the clay will occasion a rent or imperfection in the same. It is also very uncertain; and if in the first process there is a failure, it becomes more difficult again in the second, in consequence of the deposite of insoluble salts, arising from the application of water. An imperfect scouring prevents the stuff receiving the color as effectively as it should.

The oil which has been used for the greasing becomes entirely unfit for any other purpose; for, on reference to experienced men upon the subject, the result is nearly as follows: 88 lbs. of woollen cloth will imbibe 18 lbs. of oil, and they are diluted by 2843 gallons of water.

In the south, where they manufacture large quantities of common cloth for troops, or for exportation, the vegetable is not always entirely lost in the scouring. To extract this, they employ water mixed with soap and alkali: this is absorbed by heat, and then employed in the fulling of the stuff already scoured. This scouring, although very imperfect, still is, however, more economical than the former. In Sedan, for the manufacture of black cloths, &c., the greasing and the fulling are generally done at the same time. For this purpose they use a solution of soap or urine, and sometimes a combination of both. When they wish to scour the wool in thread, they use soap solution sufficiently powerful.

Messrs. Peligot and Alcan, to remove many of the inconveniences attending these processes, thought

to remedy them by the use of the acid stearic, instead of the vegetable oils. We have seen that the tallow formed into soap is transformed into two fat acids, the one solid and the other liquid. The first is the acid stearic for the manufacture of candles, and the second is the acid oleic. This last, until within the last three years, was not employed for any special purpose. These chemists, in applying it to the woollen factory, have not only rendered a great service to this last, but also to the manufacturer of stearic candles, in augmenting the value of a portion of their residue.

The employment of the acid oleic, besides economizing the actual price of purchase upon that of olive oil, or that from grain, offers this very important advantage—that it is immediately soluble in the carbonate of potash, with which it combines in the formation of soap. The scouring becomes a chemical process—for it consists in immerging the stuff for some instants in an alkaline water, and then washing it in an ordinary apparatus.

The scouring of the threads by this process has a still greater advantage, because it can be effected simply by an alkaline solution, instead of the more costly employment of a considerable quantity of soap, and equally in employing the fresh residues as in former ones.

This process is again very economical, as it furnishes itself the soap to be employed in the fulling, an operation which generally follows the scouring. The oleic acid having the direct property of a true soap, by its combination with carbonate of potash, a property that none of the vegetable oils possess in any degree or shape whatsoever, (and of which an exclusive use was made,) they now obtain, as a consequent residue from the scouring, a liquid combining the properties of soap and alkali, which before they had to provide for the fulling of the stuffs.

Besides the waste in picking, of little moment when they employ the ordinary oils, this is completely saved by the facility of scouring offered by the use of the acid oleic.

From numberless experiments it is proved, that the wool greased by the acid oleic does not become heated, neither does it ignite even when placed in circumstances most favorable for combustion.

The acid oleic, such as is left by many factories of candles, could not be employed for the purpose of greasing wool until it has undergone a complete purification, or been brought into a homogeneous substance possessing all the above-mentioned characteristics. That which they employ at this time in the cloth factories can only be compared, by its clearness and color, to the finest olive oil employed in the same factories.

In certain factories of the stearic candles they manufacture with the acid oleic a hard soap, which is sold to the dealers in large lumps.

Apparatus necessary for the manufacture of Stearic Candles.—Horizontal press, or hot press, as represented in Fig. 653, including injecting-pump.

Vertical, or cold press, with iron columns and injecting-pump.

Cast-iron chest, as in Fig. 655, for the heating of the plates.

The troughs (deal) for cleansing and decomposing, with the iron frets which surround them.

The pipes and lead casing—the agitators and their movement.

Steam-engine, high-pressure, 4 horse power.

Two boilers, each from 16 to 18 horse power. Also many other indispensable accessories, such as moulds, heaters, transmitters of movements, and pipes.

CANNON. See Ordnance.

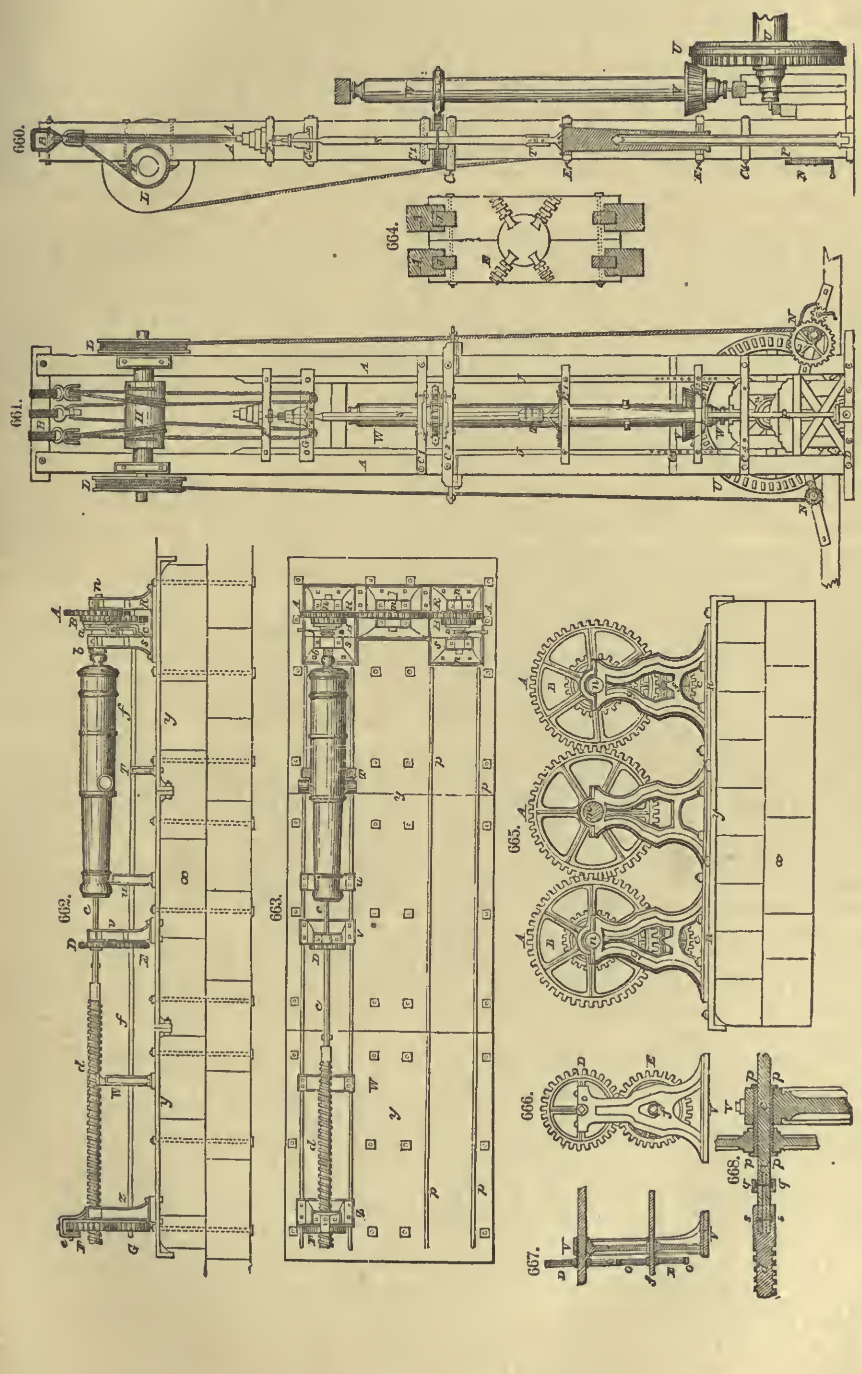
CANNON. *The Machinery for the Boring of.* The manufacture of cannons is divided into two branches, the *founding* and the *boring*. Here we only treat of the latter branch, and restrict ourselves, concerning the founding, to the remark, that formerly the cannons were founded over the core, (as it is called,) or with the bore, which then was perfectly regulated by means of the borer; while at present they are generally founded massive, and afterwards bored in *boring-mills.*

These boring-mills work either *vertically* or *horizontally*. The former were exclusively used until the middle of the last century; the boring consisted only in the enlargement of the founded bore conformable to the calibre, and the opinion prevailed that brass cannons could be bored in no other manner than this. But since then the advantages of the horizontally-working boring-mills have become so apparent, that but few of those working vertically are still extant. A short description of the three principal systems of the latter will therefore be sufficient here.

In the machines constructed according to the oldest and most imperfect system, the cannon rests vertically, and with the grape upwards, in a wooden sledge which runs in the furrows of two side-beams, and can be moved up and down by means of long tackles. Beneath the cannon, and in the direction of its axis, is the borer running in a steel pan and crossed by a beam, by means of which it is turned round by horses. The pressure required while boring, is effected by the weight of the sledge and cannon, and can be regulated by counterbalances. But as the borer is to have some scope, the borer can easily be brought out of its vertical position, and thus the boring assume a false direction without its being noticed instantly.

According to the second system, the cannon rests with its muzzle-face on rollers, while its grape is inserted into the shaft of a dented wheel connected with a moving power, and thus the cannon is turned round its axis. The vertically standing borer is fastened at a sledge, which runs in the furrows of two beams, and can be pressed onwards against the cannon during the operation of the boring, by a lever drawn upwards by a string provided with weight-stones, and passing over a pulley. Both the exact direction of the borer and its uniform pressure against the cannon is hard to be effected; yet the advantage is here, that a false direction of the borer can instantly be noticed by the trembling motion of the cannon and borer.

The third and best system of boring-mills working vertically, is represented by Figs. 660 and 661, in front view, and section through the axis of the cannon and boring-bar. Here the borer is fixed, while the cannon turns round its axis, and moves up and down in a sledge, and by its weight the required constant pressure against the borer is effected. The square piece of the cannon's grape is clamped into the *muff* marked with T, and which at the same time takes up the lower square part of the boring-



660. 661. 662. 663. 664. 665. 666. 667. 668.

spindle S. The latter is, together with the cannon, turned round their common axis by a motive power between the fixed rails C_1 and C_2, by means of the cog-wheel U, the spring-wheel V, and a cog-wheel at the vertical shaft W. The boring-spindle is provided with a bell-shaped runner of brass, whose feet turn on a steel plate inserted into the rail G. In order to secure the position of the boring-spindle, the latter has at its upper end an indentation for receiving the steel point of the bolt F. The cannon is kept in a vertical direction by the slides of the rails E_1 and E_2, provided with adjusting screws. The hitherto described contrivance moves, with the exception of the moving power between the side-beams A, right up and down, the directing-beams I, together with the rails F, G, E_1 and E_2, forming a sledge, which by means of the drawing-machines N, the disks L, their shaft F, and the long tackles fastened to the upper bolt B, can be lifted or lowered at pleasure. Fig. 664 shows the rail E_1 in the upper view, and illustrates the working of the directing and running beams one into the other, and at the same time the fastening of the rails to the directing-beams. The boring-bar is fixed in the sill D, and is kept in its vertical position by the rails C_3 and C_4. The upper rail C_3 is taken off, as soon as the cannon sinks down into its vicinity. The drawing-machine is, during the boring, slackened, so as to allow the weight of the cannon to act freely. With larger calibres, counterbalances may be applied to decrease the pressure.

The first *horizontally* working machine was constructed in 1744 at Strasburg, by Maritz, inspector-general of the foundries in France; and since these were constructed, other machines on the same principle in Spain, Sweden, and England. The boring-mill at Chaillot, in France, is the first where the power of steam was applied; and that of Liege, in Belgium, is the most extensive, comprising twelve horizontal boring-benches put in motion by four steam-engines. In both, the system is that of the cannon turning round its axis, while the borer presses straight onwards against it. Another system prevails in English boring-mills, according to which the borer is not only pressing against the cannon, but at the same time rotating in a direction opposed to that of the cannon. Machines constructed on this system are called cylindrical boring-machines. A third system unites with the contrivance for the movement of the boring-sledge a uniformly advancing support for turning off the cannon.

We shall first describe the machinery according to the above-mentioned system, applied in the boring-mills of Chaillot and Liege.

Figs. 669 to 677 represent a boring-bench and its single parts. In the mill of Liege three of such benches are placed by the side of each other, and are put in motion by a steam-engine, which is directly connected with the shaft of the middle boring-bench, while the dented wheels B are acting upon those of the side-benches. If two boring-benches be placed at the end of each other, so as to have one common axis, they form what is called a boring-road that is connected with the prime mover in the way of running boring-machines, which shall be described below.

Each bench, Figs. 669 and 670, consists of two long beams joined by cross-beams. The first two cross-beams bear the sockets A and C of the axis, the next following two bear the saddles for the grape and the mouth of the cannon, and the fifth and sixth serve as supports for the dented bar of the boring-sledge, so that the beams can be placed and kept exactly in the same level: the timber must be completely dry. The cross-beams are firm with the exception of the fourth one, which by double springs moves in the furrows of the side-beams, as the different length of the cannons requires a corresponding position of the saddle for the mouth.

For connecting the cannon with the axis, the square adjoined piece of the grape is to be put, together with the square of the axis, in the muff D, which is fastened by small metallic wedges, driven in at both sides. The cannon rests horizontally in two collars E and F, which in Figs. 673 and 676 are represented in double scale. The socket of the grape E supports the latter only on the lower side, and can be moved forwards and backwards on the beam. The socket F of the mouth embraces the cannon entirely near its head-moulding, and allows it no other movement than the rotation round its axis. The construction of these sockets (which are to be provided with copper standard-disks *a*, conformable to the calibre) may easily be comprehended by the figures. The iron boring-bar *a*, (Fig. 670,) is put with its back-squared end through the bow G of the carriage-frame, and held fast by a peg. The dented bar H is fastened in similar way to the carriage, being put through the bow *b* to G, and held fast by a fore-lock-bolt. The carriage-frame (Fig. 674) is made of cast-iron, and is moved by means of four wheels, running on the rails *c* of the long beams. The carriage must be of such weight, that it is not subjected to vacillation; while the boring-bars are made as light as possible, yet at the same time strong enough to prevent them from bending.

The means for the movement of the boring-sledge are very various. In the first boring-mills working horizontally a dented bar was applied, put in motion by an endless screw or winch; then by means of chains passing over rollers, and moved by a lever and weight-stones; and by a screw-spindle, whose box was fixed in a wheel. Yet all these means of movement require either an experienced operative, or they do not produce a uniform pressure. For this reason the manner of movement represented in the delineation was applied in the boring-mills of Chaillot and Liege. It consists of a dented bar F, moved onwards by the moving power I, at the axis of the dented wheel R, and by the action of the lever K, charged with weight-stones. The lever K is at both ends provided with the segments N and O, in whose grooves the string of the weight-stone P (which brings about the pressure) and the chain of the iron hinge M are placed. The hinge (Fig. 677) consists of two parallel iron bars joined below by two tenons, which latter stand asunder at equal distance, as two cogs of the obliquely dented wheel R do. By this contrivance a uniform pressure of the borer against the cannon is brought on, but at the same time it has the inconvenience of frequent shifting of the hinge. For this purpose, first the lever L is to be laid in to prevent the retrogression of the dented wheel, and then the weight-stone P is to be drawn up by means of the rope fixed at the segment O, and passing over the roller Q to the axis T; a catch V preventing the retrogression of this axis, turned by the moving power U. As soon as the hinge M is shifted, and the catch V lifted, the weight-stone P begins its action again. In order to cause less interruption, in the most modern French boring-mills, the dented wheel is provided with a barrel, over which

passes a string with a weight-stone at its end. The string must also pass over a roller, which is to be fixed as high as possible, to prevent a frequent hanging of the weights. It is well to provide the string with rings, one foot asunder, so as to be enabled either to increase or decrease the pressure, by hanging several weights one above the other. The movement of the boring-carriage must above all be uniform, without any start or pull. For this reason the screw-spindle is to be preferred to the dented bar, but the difficulty to make it exactly in these dimensions, and its expense, have prevented its general application.

Fig. 675 represents the frame forming the socket for the moving power of the dented bar, and at the same time holding in its lower part a roller with projecting edges, to facilitate the movement of the dented bar, and to keep the latter in the direction of the cannon-axis, conjointly with the notch in the back cross-beam.

A boring-bench arranged in this manner is adapted to great guns of every calibre; however, in more extensive boring-mills, there are several benches of inferior length for the boring of howitzers and mortars.

The *second* system of the horizontally working machines is an imitation of the above-mentioned cylindrical boring machines. Two boring-benches at the side of each other are represented in Figs. 662, 663, and 665, plan and side view. The prime mover being here either the power of steam, water, or animal power, the toothed wheel of the principal axis *m* grasps the cog-wheels A of the two shafts *n*, which belong to the boring-benches, and puts the whole boring contrivance in motion. Sometimes each of the shafts *n* is arranged for two boring-benches, in which case the second ones are placed in the king-pieces of the represented boring-benches, at the other side of the spring-wheels. The cast-iron sockets of these shafts rest on a foundation X, made of square stones, and covered with plates of cast-iron. These plates Y are firmly fixed to the foundation by screw-bolts, and are kept together at the edges by other bolts. At each boring-bench in the socket-plates are two long and well-polished grooves *p p*, for receiving the screw-bolts of the cast-iron saddles and tressels T, U, V, W, Z, as well as the support for the turning off. Along the grooves are cut out in the foundation, channels for the reception of the bolt-heads which are wider than the grooves. By this contrivance the tressels can be moved and adjusted by the screws. The screw-bolts are altogether of the same dimensions, and can be taken out at proper places, which enlargements of the grooves are to be closed by stops of iron. By taking down a tressel from the boring-bench, the female screws need only be unscrewed, and the tressel to be lifted a little, to free it from the bolt.

The socket of the shafts is formed of six iron posts, resting on a strong cast-iron plate, fixed by means of screws. The two middle posts enclose the spring-wheel of the principal axis, while the other, R and S, leave sufficient room for the wheels A, the pinion B, and the pillow-block *a*. The pinions B are screwed on the wheels A, and grasp in the cogs of the moving power *g*. C may be in equal direction with the wheels A. The cannon is, with its grape, connected with the shaft *n* by a muff; it turns round its axis, and is at its mouth supported by the saddle U. The squared shaft *f* of the lower wheel C passes through the post S and the saddle U, between which it is supported by a tressel T, and is immediately behind the resting tressel V and the winding tressel Z, provided with the cog-wheels E and G, which are fixed by means of wedges. The cog-wheel E grasps in D, placed above it, and causes the boring-bar *c* and its screw-spindle *d*, to turn on their axis in a reverse direction to the rotation of the cannon, by which the acting of the borer is strengthened. In order to produce a uniform and properly measured advance of the boring-bar, the system of the screw with moveable box is applied, the cog-wheel G working in the teeth of another one F, which contains the box of the screw-spindle *d*, and turns round this latter with somewhat less celerity than the screw-spindle itself, by the working of the cog-wheel D upon it. In this manner a slow, but uniform advance of the boring-bar is effected. The extent of the pressure of the borer against the cannon depends upon the number of the wheel-teeth, as well as upon the length of a screw-worm of the spindle, and may consequently be altered by a shifting of the wheels.

In order to afford a clearer idea of the whole machine, we shall give a more circumstantial description of its several parts, in whose construction various alterations can be made.

The shafts *n* and *f* are provided with moving-out apparatus, which are not constructed like the common claw-boxes; one of them is represented in Figs. 680 and 681. The shaft $n\ n_1$, is cut through at x, and consists of two parts, of which the front one bears the spring-wheel, while the back one, n_1, passes through the post S, and terminates in a square for the connection with the cannon. Both shaft-parts are connected with each other by a case, embraced at its front collar by a barnacle-ring *f*, which presses against the knobs *d d* of the wheel, and causes a simultaneous rotation of the box and shaft. The front part of the shaft n_1 is squared, and thus put in motion directly by the box, while the part of the shaft *n*, inserted in the box, must be cylindrical, so that the box be put in again, by means of the fork *a*, at every movement of the rotation. Suppose both shaft-ends inserted in the box were square, it would be not only difficult to watch the moment when both shafts are in congruity, but also impossible to prevent a shaking movement. The fork *a* moving round the support *b c*, fixed to the post S, embraces the box at the groove of its weaker back-part, and leans against the projecting edges. Thus, if the handle of the fork be pressed to the left, the box is moved out to the right, i. e. the barnacle-ring *f* leaves the knobs *d*, and the movement of the shaft *n* is not connected with its other half n_1.

The saddle U is represented in Figs. 684 and 685; it has, like all other tressels, in its lower part a socket for the shaft *f*. The slide *o*, forming the holder for the cannon-mouth, is adapted to every length and diameter of the cannon, and is provided with adjusting disks polished with emery. The lower part of the slide is cut off obliquely, and in conformity with the inclination of the wedge, moved by the screws *m n*. Consequently by drawing the female screw *m*, the cannon can be lifted exactly to the required height.

The supporting tressel T of the shaft *f* is represented in Fig. 686; it contains the semicircular socket in its upper part. The squared shaft *f* is at all points, where it rests on the tressels, provided with

brass boxes, which are circular at their outsides, and fastened at the shaft by means of small metallic wedges.

Figs. 666 and 667 represent the resting tressel V, whose upper part contains the holder of the boring-bar *c*. The latter being squared, it is provided with a box *p p*, Fig. 668, circular at its outside, and turning round in the holder, together with the bar, yet not advancing like this. To the projecting squared part of the box the toothed wheel D is fixed, which puts the boring-bar and screw-spindle in a rotative movement. To the lower shaft *f* is fixed the wheel E, which can be kept in constant gearing with the wheel D by the edge *o o;* otherwise the box might, together with the upper wheel, slip out of the socket.

The tressel W, Figs. 682 and 683, supporting the spindle and lower shaft, has at its upper part the slide *b*, and is cut out conformable to the diameter of the screw-spindle.

The hindmost part of the machine is formed by the tressel Z, Figs. 678 and 679, which allows a free passage to the screw-spindle, and is for this reason perforated according to its widest diameter. Above, the tressel contains the holder for the shaft of the wheel *e*, which allows to draw back the boring-bar by means of the winch *x*, and at the same time to increase or decrease the pressure against the cannon, if required. The wheel *e* works in the teeth of the cog-wheel F, which contains the female screw of the screw-spindle, and is kept in constant gearing with the wheel G, by the edge *p p*. Thus, whenever the boring-bar is to be drawn back, the wheel G is drawn off, and the lower shaft *f* moved out.

Should it seem preferable to allow a spring-like movement to the boring-bar, the tressel V may be entirely removed, and then the wheel D is to be fastened at the square end of the screw-spindle, which now, together with the boring-bar, is moving onwards against the cannon.

The third system of the horizontally-working machines is a combination of the two other ones. The arrangement of the wheel-work and shaft-sockets A and B is in substance the same as the above described. The boring-shafts are provided with apparatus to move them out and in; yet the connection of the cannon with the principal axis is arranged in an improved manner. The adjoined piece of the grape has the shape of a regular prism, and is inserted into a box cylindrical at its outside; at the end of the axis is fastened a ring. In the cylindrical excavation, D, the inserted box, has a play of some few lines. Three strong adjusting screws pass through the adjoined piece into the box, and by means of them the cannon can be centred, if required.

In general the cannon is only supported at its mouth by the saddle G with the disk *a;* with great calibres, however, a second saddle G_1 may be applied at the bottom piece or grape. The saddles are made of cast-iron, and moveable in the grooves of the iron plates.

The sledge L, made of brass, terminates below in a guide, which is advancing in the excavation Y, and cut out in such manner that it forms beneath the screw-spindles, two feet armed at the edges with steel rails. At the middlemost and higher part of the sledge, the boring-bar is fixed either by means of a bow and pin, or of two steel rails R, that are to be screwed on, and between which the square of the bar is pressed fast by the screw *d*. The shifting of the borers and the taking out of the bore-chips is so facilitated. The sledge is pressed against the cannon by two screw-spindles E and E_1, passing through the side projections of the sledge, and having their sockets in the iron posts B and N. The female screws are cut out in the brass of the sledge, and at both ends provided with steel armaments. The back ends of the spindles, terminating in squares, bear the toothed wheels O and O_1, being in gearing with each other by the equal wheel O_2, and thus turning in the same direction, and with the same celerity. The spindle E passes through the post N, and is provided with a handspike-wheel P, for the movement of the machine.

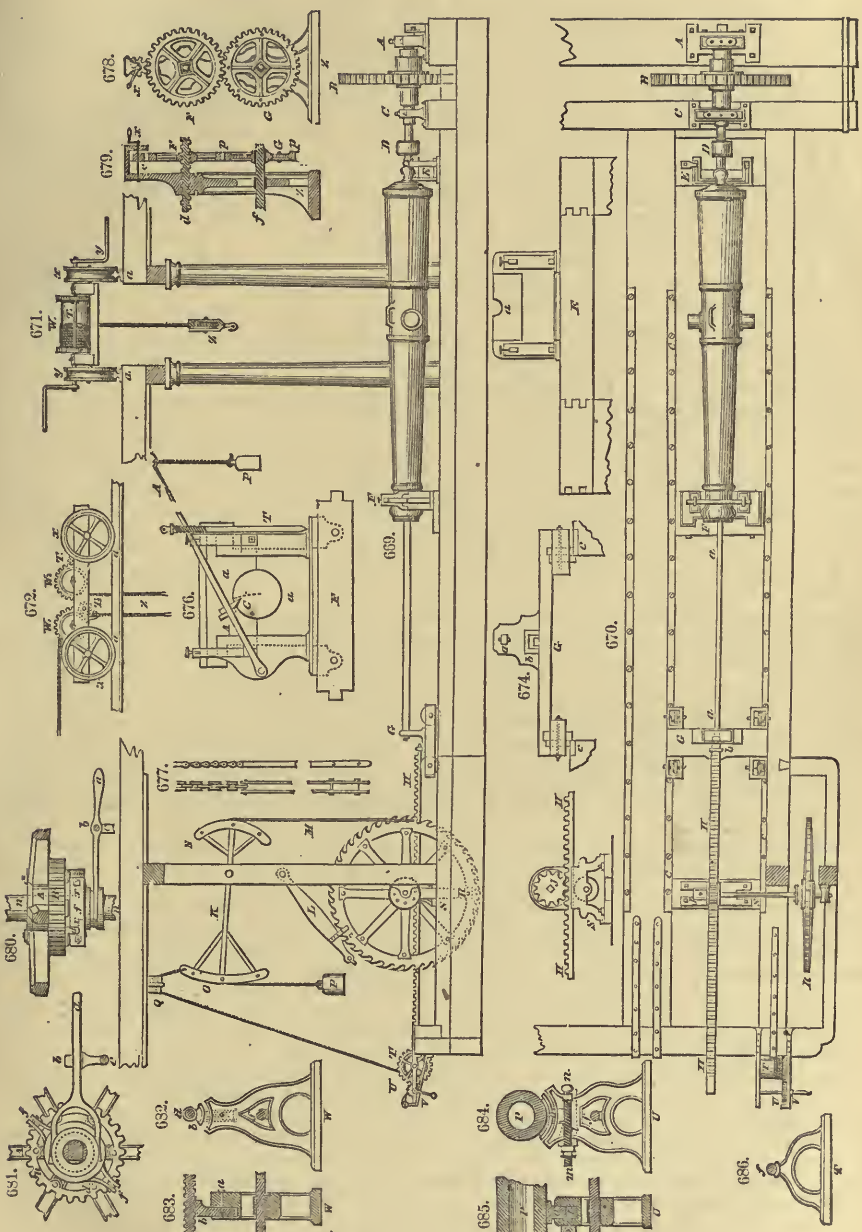
Simultaneously with the sledge, a support K, for the turning off, moves along the cannon, and is provided with a female screw for the spindle. It has, like the sledge, a guide sliding on the iron plates or special bolts, and through the upper part of which a brass wing H is moving, and terminates in a foot gliding on the steel rails *c c* of the iron plate Q. The latter is, according to the various descriptions and calibres of the cannon, fixed at the screw-holes *x x*, so that the rails *c c* run parallel with the cannon, while the turner's chisel is always kept in a proper distance from the cannon's axis during the movement of the support. At the front end of the wing H is a moveable rail or peg, for supporting the turner's chisel; by means of an endless screw it can be put back or forward, and an index at its upper side indicates the extent of the change.

At Douai, in France, a steam-engine, 12-horse power, moves four boring-benches, whose shafts make 10 or 12 revolutions a minute; at Toulouse, a water-wheel, 12 or 13-horse power, moves four boring-benches; and at Strasbourg, one boring-bench is put in motion by four horses.

The movement of the cannon on the boring-bench, and the pressure required against the borer, depend generally upon the material and calibre of the cannon. Is the rotation decreased, the pressure may be increased, as otherwise the bit might generate a too great heat, and thus become weak. Iron cannon and wide calibres must revolve more slowly than brass cannon and smaller calibres. In the boring-mill of Liege, the cannon revolves once in 8 seconds, and in that of Douai it revolves at the rate of 10 or 12 times a minute. It seems that 12 times a minute is considered as the maximum.

The pressure, depending chiefly upon the hardness of the metal, cannot be indicated precisely. In the second of the horizontally-working machines, above described, the advance of the boring-bar depends upon the number of teeth of the several wheels. If, for instance, the wheels B, C, D, E, and F, have 36 teeth each, while the wheel G has only 34 teeth, the wheel F, together with the female screw of the spindle, will make $\frac{34}{36}$ of one complete rotation of the spindle; and thus the boring-bar will advance only by $\frac{2}{36}$ of that distance, by which it would have moved onwards, if the female screw were fixed. If the length of a screw-worm be half an inch, the spindle will advance by $\frac{2}{36} \times \frac{1}{2} = \frac{1}{36}$ inch. Should the wheels B, C, E, and F have 36 teeth each, while the wheel D has 35, and G only 34, the spindle will revolve at the rate of $\frac{36}{35}$, and the female screw at that of $\frac{34}{36}$ of one complete rotation of the cannon, while the boring-bar is advancing by $\frac{36}{35} \times \frac{2}{36} \times \frac{1}{2} = 0{\cdot}0286$ inch.

The following table gives the number of teeth both of the spring-wheels and of the wheels E and F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The middle wheel of the lower axis, and that with the female screw, are at all events provided with 36 teeth; by inserting a fresh boring-bar, the proportion of the advance can be altered without much trouble.

Borer.		The Material, Description, and Calibre of the Cannon.	Number of teeth of the wheels.			Advance of the boring bar by inches.		Remarks.
			B, C, E and F.	D.	G.	During one rotation of the cannon.	In an hour.	
Plain borer and widening borer.	Brass cannon.	From 48 to 24 pound cannon, mortars, carronades, and howitzers, of wide calibre	36	35	34	0·0286	10·29	The length of a screw-worm is ½ an inch.
		From 18 to 12 pound cannon and howitzers of small calibre	36	35	33	0·0428	15·41	
		From 6 to 4 pound cannon	36	34	33	0·0441	15·88	
	Iron cannon.	From 48 to 24 pound cannon, mortars, and howitzers of wide calibre	36	36	33	0·0416	14:97	The cannon revolves at the rate of 6 times a minute.
		From 18 to 12 pound cannon and howitzers of small calibre	36	34	33	0·0441	15·88	
		From 6 to 4 pound cannon	36	36	32	0·0554	19·44	
Auger or forehand-borer.		Fly-borer of the mortar-pieces and auger of the carronades, and from 48 to 24 pound iron cannon...........	36	36	35	0·0139	5·00	
		Chamber-auger of the howitzers, and auger for all other great guns	36	36	34	0·0277	9·97	
Bottom-borer.		Bottom-borer of the cannon, chamber bottom-borer of the mortar-pieces, and vault-borer for the holes of the mortar-pieces...........................	36	35	35	0·0143	5·148	

To convey the cannon from the foundry to the boring-mill, a *crane-carriage* can be applied in case of their being connected with each other by a railway; which, of course, is to be held aloft by supporting-posts, that the cannon can be lowered down to the boring-bench. The carriage runs on four cast-iron wheels X, on the rail *a*. (See Figs. 671 and 672.) Its upper frame, made of solid timber, bears two shafts W_1 and W_2, T_1 and T_2, moved by winches Y. The shaft W_2 serves to move the carriage onward, and the end of the rope cast round it is fixed to a hook in the intended direction of the carriage. Sometimes this shaft is left out entirely, and the carriage provided at both ends with hooks to hang ropes, which either are fastened to windlasses at both sides of the railway, or are connected with the principal axis of the boring-mill by rollers. To the ropes of the second shaft is attached the draw-beam Z by means of strong iron hooks, to which the cannon is fixed with ropes. The axle T_1 is provided with double ratchets.

By means of this crane-carriage the cannon is lifted from the pit, freed from the mould, and then conveyed to the boring-bench, on which it is placed horizontally. In a similar manner it can be removed as soon as the boring operation is accomplished.

Before the cannon is encased on the boring-bench, its eccentricity must be examined; for which purpose it is to be placed on two separate saddles, where it is, by means of the trunnions, turned round its axis and meanwhile examined. If the eccentricity nowhere exceeds four lines, the cannon may forthwith be encased; but in the contrary case its centre must previously be precisely regulated.

For the purpose of severing or turning off the *lost head*, the lever A, Fig. 676, centred on a pin at the front saddle or tressel F, or at a particular post, moves in a plane vertical to the cannon, and has in its lower part a hole, into which is inserted the chisel-shaped blade C. At the lever's end is the weight P, and above it a moveable ear or handle, serving as box for the support T, which, at its upper part is provided with screw-threads. By means of this screw the chisel can be approached to the axis of the cannon, while the weight prevents the rising of the apparatus. The boring-mill being put in motion, the lost head is turned off to a minute remnant, whereupon a stroke completes the severing.

For the purpose of the cannon being centered, near the cannon a cross-piece of timber is put beneath the boring-bar, which is then, by means of small wedges, to be brought to the required height and direction. This done, and the front face of the cannon having been chalked, the borer is slightly pressed against it, while the cannon revolves. If no shaking of the boring-bar be perceived, even by increasing the pressure, the borer is correctly centred; but if it be the case, the boring-bar must, by the wedges, be adjusted till no shaking is perceivable. Now the boring may commence.

The shape of the borer has in the course of time greatly varied. Formerly a hollow borer or wimble was used for boring massively founded cannon over the core, as it was called. Having bored to a certain depth, the core was, by a peculiar contrivance, pushed off, and upon this the boring operation completed with borers. This was performed in boring-mills, working vertically.

At present there are chiefly four descriptions of borers in use, viz :—The *auger*, the *bottom-borer*, the *plain* or *calibre borer*, and the *widening-borer*.

The terms of *cross-borer*, *disk-borer*, *bore-knife*, *chamber* and *fly borer*, *vault-borer*, &c., have relation

partly to peculiar positions and shapes of the bits, partly to the place and manner of their application, and can be ranged in the above-named descriptions.

The *auger* consists commonly of a bit of steel as broad as the first boring requires. Frequently hardened iron is used instead of steel. This auger is used in the boring-mill of Liege. It has two edges and an angular form in the fore part. The angle must be the more obtuse, the greater the motive power, the pressure, and the hardness of the metal. By this bit the first boring is preserved to the distance of four lines from the cannon's bottom, where it ends in a conical form. With middle calibres the bore of the cannon is now only to be somewhat widened and polished, by means of the plain borer, while with larger calibres one or more widening borers are still to be applied.

The older French auger, here and there still in use, consists of three blades, the first of which having the form of the auger and widening the bore to two-thirds of the whole boring diameter. Behind it, in the bit-head, is a hole, through which the second blade is put, that cuts onward and sidewise, and widens the bore by eight lines. Behind, and in a right angle with this blade, is a third, which widens the bore to the diameter required for its being polished.

In German boring-mills, augers are used; they leave four lines of the bore, and penetrate to near the bottom of the cannon or howitzer. In recent time the form of a saw, like that of the bore-knives, has been adapted to the auger; and thus, by one single boring, the operation can be completed so far that only the plain borer is still to be applied. In Vienna the augers have not only this form, but are also provided with shovel-edges.

In order to be assured of the correctness of the first boring, a strong wooden rule as broad as the bore, is to be put in; and in case it can penetrate to the bottom, and be turned without any obstacle, the boring is faultless and can be pursued.

The boring with the auger is immediately followed by that with the *bottom-borer*, though with larger calibres, an application of some widening borers is to be made previously. The bottom-borer is intended to widen the cone made by the auger, and give the required shape to the bottom. Its boring-blade is three or four lines thick, and forms a rectangle, rounded off in the fore part, which at the same time is the cutting part. The frame or head of the borer is, by means of its tail and by two screws, fixed to the boring-bar.

The next is a bottom-borer, as constructed in France; and another one intended for giving a hemispherical form to the bottom. The latter can be forthwith applied, in which case it consists of a metallic head provided with two side-blades, and an upper rounded edge; four wooden prisms secure the run of the borer. Frequently the head receives a cylindrical form, and the boring-blade is inserted, in the way of a plane-iron; in which case the borer is called a *disk-borer.*

The bottom-borer is followed by the *polishing* or *plain borer*, which commonly only takes away the two last lines of metal and polishes the bore, by freeing it from boring-rings. Its head forms a cylinder, a quarter of which is cut out, and on the level of its edge an oblique steel blade is screwed fast The screw-holes in the blade are elliptically formed, as the boring is to be repeated several times, and meanwhile the discharge of the blades is gradually increased until the normal calibre is attained.

The plain borer is used in the boring-mill of Liege. It consists of two small boring-blades, which, in the fore part, have exactly the form of the bottom, and are fixed to the tongue of the boring-head by means of three screw-bolts. The discharge of the blades is effected by strips of tin-plate inserted behind their back.

The boring of the howitzers and mortars is in general done in the same manner as that of the cannon, with the only exception that a greater number of borers is applied. The auger is succeeded by the calibre-borer of the chamber; it is intended to polish the chamber; and as its blades are crossing each other, it is also called the *cross-borer.* The third and fourth borers have the same frame, into which the blades are inserted one after the other. At last follows a polishing-borer. The gradual discharge of its two blades is effected by inserted small strips of tin-plate.

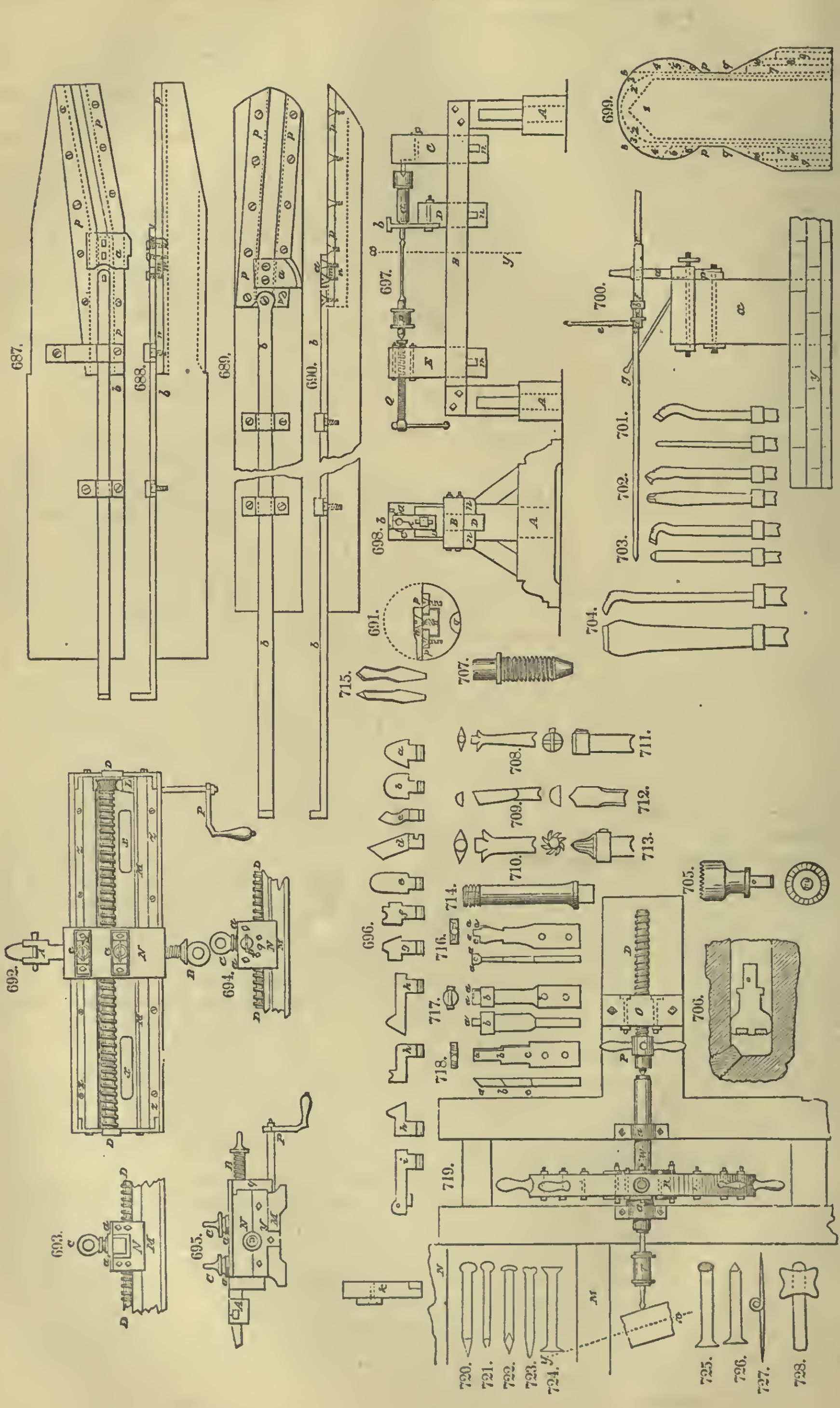
Field-howitzers, with spherical chambers, are in France bored with borers of the following description:—A common auger makes a bore, which is by two lines less wide than the chamber. Next follows the borer which bores out the fly or middle part of the bore to two lines of its diameter; a cylinder of the same diameter as the first bore serves as guide to it. The third borer has a similar guide, and is intended for boring out the spherical chamber. Then follow the polishing-borers

The mortars are, in the boring-mill of Liege, bored in the following manner:—First is applied the small auger, which makes the bore by four lines less wide than the chamber. Next follows the great auger, which is inserted into a particular boring-bar, and penetrates to the fore part of the chamber. Its blade can either be formed single, or be composed of three blades; the joined piece of the boring-head serves as support. After this the chamber-borers are applied.

In case the chamber is to be conically formed, the *bore-knives* are commonly used, which are constructed in the following manner:—At the boring-bar is a long groove for receiving the dented iron rail, which is held by the bands. The bar is moved by the axle, and by means of the lever, and at its front end is a notch, into which the boring-blade is inserted after the plate has been removed. The lever is worked by an operative. The first bore-knife to be inserted is in the form of a saw, and brings about an undulatory surface in the chamber; yet with the advantage of taking away much metal. The second one is plain, and cuts away all elevations completely.

Another instrument for boring conical chambers is represented by Figs. 687 and 688. The blade *a* is, by means of the bar *b*, moved onwards in grooves formed by the lists *p p*, and is, like the bar *b*, screwed in the plates *m* and *n*. The surface of the instrument is plain, whereas the lower base is rounded according to the form of the chamber, (see Fig. 691.)

The boring of spherical chambers is very different; it requires a great number of borers. To show their contrivance and application, we will shortly describe the boring of a French foot-mortar. First an auger is applied, whose diameter is by 4 lines less than the neck of the chamber. Next follows the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blade, together with another rounded in accordance with the form of the chamber. Fig. 699 illustrates the shape of the borings, which are marked with ciphers in their order of succession. All these blades are inserted into the head of a particular boring-bar. The chief part of the head is provided with a tongue, and a cover or moveable lip B, on which all blades are screwed. The grooves of the blades are adjusted to the lists. Now as soon as they have attained the bottom of the chamber, they glide backwards in consequence of the pressure, and commence at the same time the operation of boring out the chamber. First, the blades C, then the blades D, and at last the blades E, are applied, and thus the parts 4, 5, and 6 of the chamber, (see Fig. 699,) are successively cut away. Finally, to complete the boring, the blades and the polishing-borer are applied.

Figs. 689, 690, and 691 represent a borer for giving to the chamber the form of a pear. It is applied after a bore as wide as the chamber-neck having been made. The boring-head has a groove q to let out the bore-chips; and in another groove, partly covered by the rails $p\,p$, run the plates m and n, round which the blade a, and the bar b are fixed. It may finally be remarked that the pear-formed chambers are at present out of use.

The *turning off* is at present commonly done conjointly with the boring of the cannons. Only in boring-mills working vertically, a separate turning-lathe is required, which consists of two long beams 6 or 8 inches asunder, and short cross-beams. In the inside grooves of the long beams are inserted two moveable strong oak blocks, provided with knobs or bunchings at the front, to be inserted into holes of the front and back pieces of the cannon. Near the trunnions is a disk, consisting of two halves, fixed and connected by an endless thong, with a fly-wheel of five or six times greater diameter. In this way the cannon is turned on its axis.

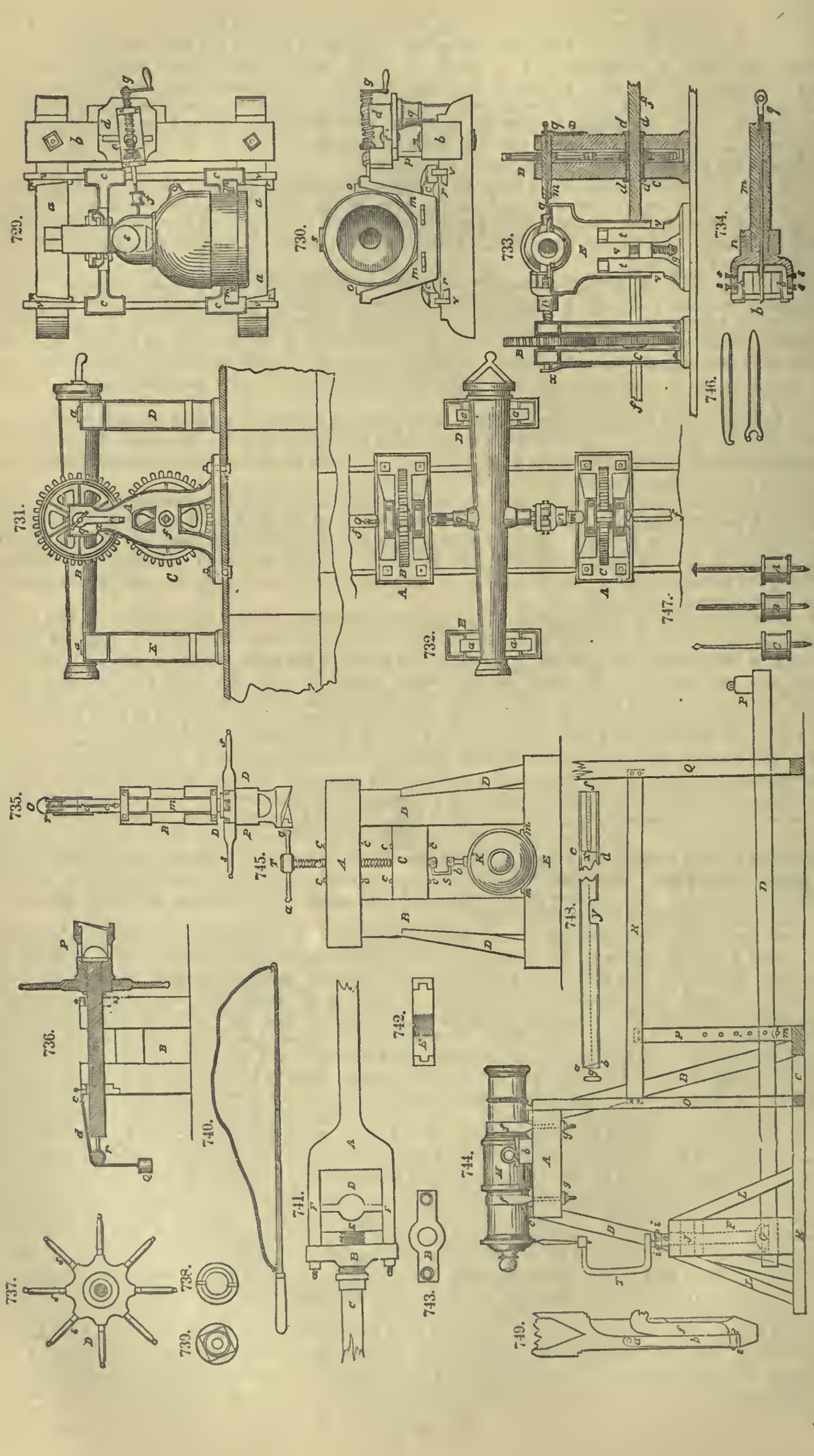
The turning off can be done either off hand, or by clamped chisels. The first method has many advantages, yet requires great labor, and an experienced operative; and the apparatus for working by clamped chisels on moveable supports is very expensive, however applied to brass cannons. The common method is the working off hand combined with fast supports.

The turner's chisels are provided with long wooden handles, and are either crooked (as the French) or straight, (as the English.) The French chisels are dented at the back of the incurvation, to prevent their slipping from the support. There are especially two descriptions of them, the one intended to rough-turn with, and the other for planing, (see Figs. 701, 702, 703, and 704.) The English chisels are straight, and mounted with either triangular or quadrangular pommels; the handles are fastened to them in right-angular direction.

A moveable support according to the old French system is represented by Figs. 692 to 695, and worthy of description here, as it can yet be applied with some modifications. The chisels, Fig. 696, are by means of a bolt fixed in the iron rail A, which in the wings of the brass support N can be moved onwards and backwards by the screw B. The latter passes through the back part of the support, strengthened by the steel plates q. To prevent the rail A from lifting, the two cross-pieces $a\,a$ on the support, are provided with female screws for the pressing-screws C. The support N rests on the brass plate M, and is moved on it by the screw-spindle D, which passes through its midst, where the two ends of the screw-worm are armed with the steel plates Y. The lowest part of the support consists of a foot running in a furrow of the plate, and regulating the progress. For the purpose of facilitating the movement, and maintaining a uniform and easy progress, the steel rails $z\,z$ are inserted along the plate. At one end the screw-spindle is provided with a toothed wheel in gearing with the winch P, by means of the endless screw L. According to the older system, the plate was fixed to the boring-bench by two screw-bolts passing through the cuts X X; but at present one single bolt is applied, and passes through the middle of the plate. The chisels used with the moveable supports are in general shaped as is shown by Fig. 696, a and b. For turning off the moulding and grape of the cannon, particular chisels are used, such as represented by Fig. 696, b and k.

Before the turning off begins, the cannon is placed so that the trunnions lie exactly in a horizontal plane, and then, by means of the instrument, the middle line of the cannon's surface is to be ascertained. Upon this the moulding, edge-rings, and vent are pointed out and marked, so as to prevent the chisel from planing these points. In turning off hand, the beginning is commonly made with the bottom moulding, next follows the edge-ring, and then the grape, and thus the operation proceeds to the head-moulding, while successively the chisels c, d, e, f, g, a, b, h, and i, Fig. 696, are applied. The trunnions are to be rounded off, either off hand, or by a particular contrivance of the machine, illustrated by Figs. 735 to 739. The cannon rests in cross-blocks or standards, and the machinery in the frames B. The spindle m consists of two parts, one of which bears the roller r, round which the string d of the weight Q is coiled. The screw of the spindle is adapted to the female screw in the capsule P, to which is fixed the fly-wheel D. Another machine is represented by Figs. 731, 732, 733, and 734, and all its parts are made of cast-iron or steel. The sockets D and E for the cannon are by screw-bolts fixed in slits of the iron plates of the boring-bench. Each of the standards E, Fig. 733, consists of two parts, whose projections v and t grasp one into the other. The screw g serves for adjusting the required height of the upper part. The standards A A are, like the tressels of the boring-bench, fixed by screw-bolts in the long slits $p\,p$, (see Fig. 663.) Through the lower part of both standards passes the squared axis f of the boring-bench, bearing the round boxes $d\,d$, and the wheels C. Through the upper part of the standards passes the spindle m, on which are screwed the blade-baskets n, and which bears at the same time the wheels B, that, conjointly with the wheels C, bring about the simultaneous movement of both spindles. Each spindle is perforated in its axis for the reception of the steel rod q, which at its back end is provided with a screw-turn, and at its front end with a small female screw. The pressure against the cannon is effected by a strong spring x. The basket n contains four blades b, (see Fig. 734,) which by the pressing-screws s are pressed against the trunnions.

Those parts of the the cannon which cannot be turned off in the above-described manner, because the trunnions and handles hinder it, are elaborated by the chaser or engraver. The instruments he makes use of are represented by Figs. 720 to 727. First, he applies the gouge, (Fig. 723,) carving furrows, whose



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edges he then takes away by the plain chisels, (Figs. 720 and 721,) upon which the surface is freed from all inequalities by means of the vaulted mallet, (Fig. 728,) and of the instruments represented by Figs. 724 and 726. The elaboration of the angles and ornaments is accomplished by means of the burin, (Fig. 722.) Finally, the chaser elaborates the written characters, using the instrument, Fig. 727, called in French traçoir, and the common gravers. Fig. 725 represents a scalper or raspatory for dimming the metal between letters working in relievo.

We will give here some statements about the difference in time between the older and modern boring systems. Formerly it was computed that the boring of a 24-pounder might take up 8 or 10 days, its turning off the same space of time, and the transport from one machine to the other 4 days; consequently in total from 20 to 24 days, or from 200 to 240 hours. At present a 24-pounder is bored in 50 hours, the simultaneous turning off prolongs this time to 60 hours at the most, and the transport takes scarcely 10 hours; thus the whole work is done in 70 hours. The boring of smaller calibres is at present completed in 14 hours, and that of the mortar-pieces in from 20 to 60 hours. In the French boring-mills the auger advances $\frac{3}{4}$ of an inch in an hour; the bottom-borer completes its work in an hour, and the plain borer advances one inch in an hour, as also the widening borer. In the modern German boring-mills the borers advance $1\frac{1}{2}$ inches in an hour.*

To make the cannon completely ready for service, the boring of the vent, the placing of the aiming ruler, and the fixing of the priming contrivance remain to be done. For placing the aiming ruler, either a deepening is made in the back edge-ring, or a hole bored in the bottom-piece of the cannon, in the performance of which is used the borer represented by Fig. 744. The frame required for this operation consists of a standard A, of whose four feet C, only the two back ones are to be seen in the figure. The cannon rests on this standard in a horizontal position, is at its ends supported by the wedges C, and at the trunnions by the blocks *b* and wedges *a*, and is fixed by means of the bands *f* and cross-pieces *g*. Between the posts O, P, Q, and R, is the beam D, serving as a lever, having its fulcrum at *m*, and being pressed down by the weight P, by which its front end with the blade G lifts the guide I. Between the cross-rails of the bench F, the guide I can only move vertically up and down; at its upper end it is armed with an iron frame *o*, which can be adjusted by the screws *i i*. It is at the same time provided with a steel plate, through the conical deepening of which the borer T is put.

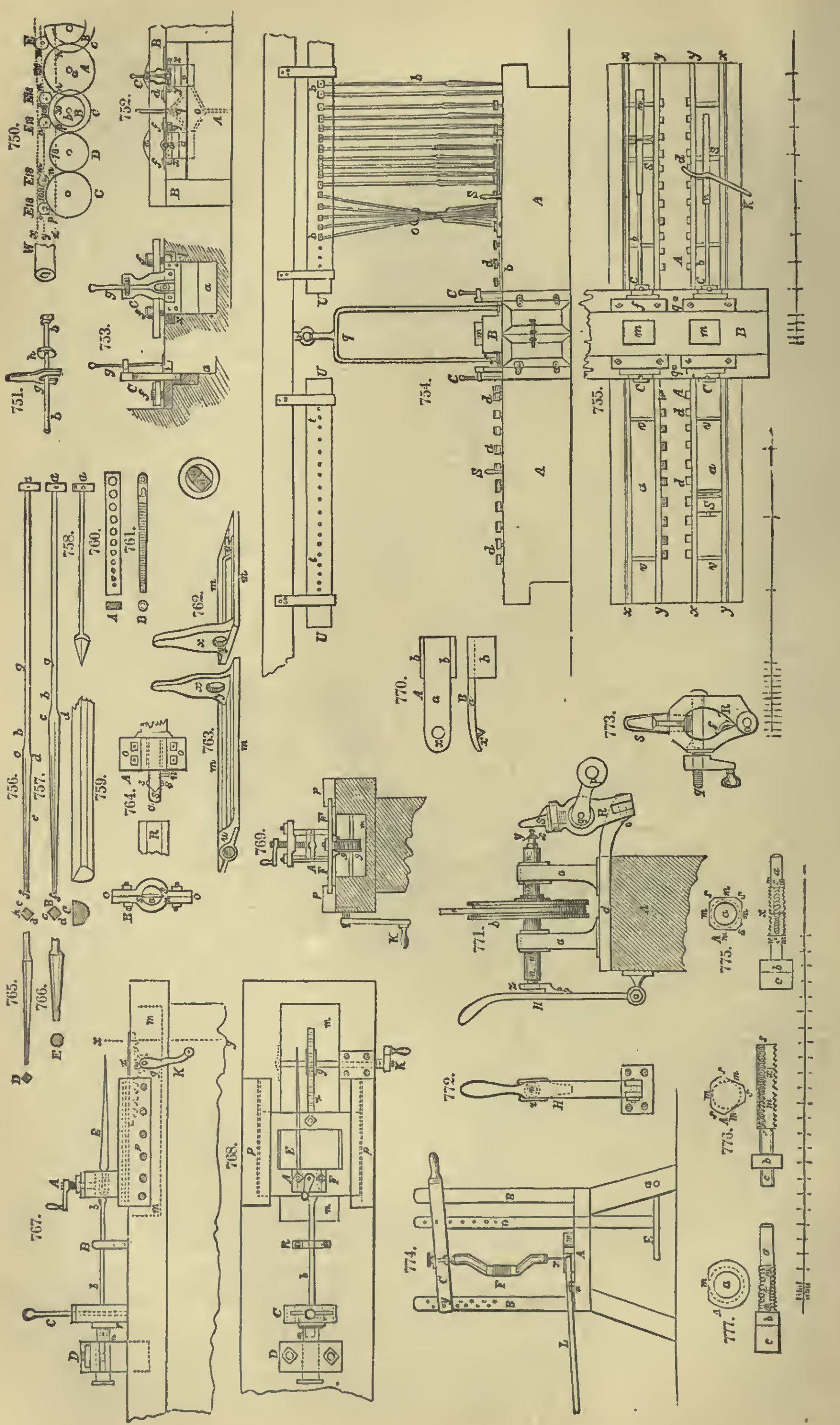
The boring of the *vent* of the cannon is performed either by a *drill* (which is turned to the right and left alternately) or by the borer T, (see Fig. 744,) which latter is turned in one and the same direction. Commonly the former is used, especially in the boring-mill of Liege, where the machine for this purpose, represented by Figs. 729 and 730, comprises two frames, one for the cannon, and the other for the drill. The frame for the cannon consists of two cross-beams *a a*, united by a long beam *b*; in the former the iron rails *v* are inserted and fastened by the wedges *r*; the cross-pieces *c c* are moveable. The tressels *m m*, with the disks *o o*, are supporting the cannon at both ends, and can be moved aside, if required, on the cross-pieces *c*. The cannon is placed in such a manner, that while the axis of the bore lays horizontally, that of the trunnions is vertical. The boring-apparatus consists of a bench *d*, fixed, by means of the bolt *e*, to a plate, which rests on the posts *q* and *p*, and on which the bench turns on the bolt *e*. The drill *f* is moved onwards against the cannon by a spindle, or by a dented bar and winch, and is turned by means of a bow, Fig. 740, made of bamboo or old steel blades, and whose string (of catgut or horsehair) is coiled round the boring-roll. By moving the bow to and fro, the borer turns alternately to the right and left. For adjusting the bench, the ruler, Fig. 748, is applied. The line *a b* marks the axis of the vent, and the line *c d* indicates the length of the cannon's bore. To this latter line the notch *x* extends. The line *f g* corresponds to the notch *y*. By means of this ruler the point for the vent can be exactly fixed. As regards the borers, in Liege first the auger C (Fig. 747) is applied, then the plain borer B, and finally the borer C. The bits are of the best steel.

To prevent the deterioration of the vent by the violent discharge of gas from it in the moment of the explosion, there must be inserted in it a pipe of iron, or of refined copper, which is replaced by a fresh one as soon as it is worn out. For this purpose the pipe has on its outside a male, and the vent is provided with a female screw. On the lathe the pipe receives the form *a* in Fig. 697. The lower part is made conical, the next following cylindrical, and the upper part squared. The boring out of the vent in the French foundries is performed by means of a machine represented by Figs. 697 and 698. The cheeks B, resting on two standards A, receive the rails C, D, and E, of which the two latter are fixed by the wedges *n n*. The pressure of the drill *p* is effected by the pressing-screw Q. The cutting of the screw-worm is performed on the block *x*, Fig. 700, by means of barnacles or pincers, Figs. 741, 742, and 743. The pipe or core *a* is clamped in the vice *b*, fixed to the block *x*, which in its lower part is firmly immured. The fork-shaped body A of the pincers runs out in a long arm; the cheeks D and E are inserted into the furrows of the arms F; the cross-piece B is held fast by the screws *x x*, and forms the female screw for the end of the lever C. The pincers are turned horizontally round the pipe by two operatives, while a third one is watching the operation. To form the female screw in the vent,

* Field-guns cannot be conveniently served when they have less than one hundred and fifty pounds of metal to each pound of shot, and battering-guns require at least two hundred pounds of metal to each pound of the shot. With any less weight the service of the gun is very difficult, from its excessive recoil; therefore, lightness is not a desirable point in the construction of cannon.

Strength is always desirable; it should be secured, but not at the expense of any other important point. If it were possible to fabricate sound and strong guns of wrought-iron, they would be found deficient in hardness. The projectiles used are of cast-iron, a material much harder than wrought-iron; consequently, the wrought-iron gun is soon indented and worn so much as to prevent all accuracy in firing, and it then is worth little or nothing.

Leaden balls are used in small-arms; but they are inadmissible in cannon, as the great heat of the exploded gunpowder melts the lead, more or less, and changes the form of the ball, thereby reducing its range; besides, lead has not sufficient tenacity to enter hard substances, and therefore is not a suitable material to be used against ships and batteries. Wrought-iron is also more liable to injury from rust, than bronze, or cast-iron; and the smallest crack admitting moisture, would, of itself, in time, seriously injure the gun. The first cost of wrought-iron cannon is the same as that of bronze, and more than six times that of cast-iron. Bronze guns, it may be remarked, after being too much worn for service, can be easily recast, whereas the old wrought-iron is useless for refabrication, and of little value, in such large masses, for any purpose.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the horizontally-working boring-bench, represented by Fig. 719, formerly was used, and is in some places still in use. But at present the vertically-working machine (Fig. 745) prevails. It consists of the frame A, B, C, D, E, a screw-spindle T, (whose female screws are in A and C,) and the borer S. The cannon rests on the beam E.

The borers commonly applied are, first the auger, (Fig. 715,) then some widening borers, and a polishing-borer of the shape in 712. With old battering-trains, or cannon of fortresses, in which the pipes are inserted in a heated state, a greater number of borers are required. In France, first an auger is applied, and then six others in the ensuing order of succession: Figs. 708, 709, 710, 711, 712, and 713.

CAPSTAN. A machine employed on board large vessels to assist the mechanical power of the crew, in the operation of weighing the anchor. It is a vertical windlass, consisting of a drum or barrel revolving on a vertical spindle, with holes near its top for the reception of horizontal levers, or *capstan bars*, to which the force of the crew is applied to turn it round. The cable is coiled two or three times round the barrel, and as the capstan is turned round by one part of the crew, another part is engaged in coiling away the slack of the cable as it unwinds from the barrel. See Crab.

CARDS. In preparing cotton or other materials for spinning, they are subjected to the carding process, by which the fibres of cotton or wool are disentangled, and arranged in a regular parallel form called a lap.

This is an important process, as regularity and perfection in carding are essential to the fineness and beauty of the cloth. Cards are formed of strips of leather, in which are inserted small staples of wire called teeth, having the projecting ends slightly bent in one direction. The strips of leather are fastened to flat surfaces or cylinders of wood or metal, and the cotton is passed between two or more of these surfaces. The teeth of cards are of various sizes, being thicker or slenderer, to adapt them to coarse or fine materials. It is essential that the teeth should be all alike, equally distributed, and equally inclined over the surface of the leather. The teeth are implanted by pairs, and retained in it by the cross part *c d*, (fig. 778,) at right angles with the teeth. The leather must therefore be pierced with twin holes at the distance *c d*, and in such a manner, that the slope of the holes in reference to the plane of the leather, be invariably the same; for otherwise, the teeth would vary with the angle of inclination, and the card would be irregular. The leather should be of the same thickness throughout, so that all the teeth may project an equal distance. Card making requires a degree of precision which is hardly possible with hand work, and they are now manufactured exclusively by machinery.

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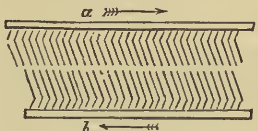

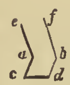

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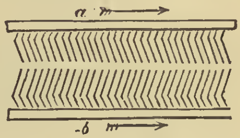

The following is a description of the card-making machine invented by Mr. Whittemore. Long sheets or fillets of leather of suitable length, breadth and thickness for making cards, are stretched by winding the fillet upon a roller or drum, from which it is conducted upwards between guide rollers, to a receiving roller at the top of the machine, where it is held by a cramp, by which means the leather is kept stretched.

The holes are pierced in the leather to receive the wire staples or teeth of the card, by means of a sliding fork, the points of which are presented to the face of the leather; while the fork is made to advance and recede continually by the agency of levers, operated by rotatory cams upon a revolving main shaft. The leather fillet is shifted so as to bring different parts of its surface opposite to the points of the sliding fork, so that the holes shall be pierced at regular distances. This is done by cams, which shift the guide rollers and confining drums laterally, as they revolve, and consequently move the fillet of leather at intervals to the distance required between the holes.

The wire of which the teeth of the card are made, is fed from a coil on one side of the machine, and brought forward at intervals by a pair of sliding pincers, moving to and fro through the agency of levers, operated by rotatory cams upon the main shaft. The pincers having advanced a distance equal to the length of wire intended to form one staple or two points, this length of wire is pressed upon exactly in the middle by a square piece of steel, and being there confined, a cutter is brought forward which cuts it off from that part of the wire held in the pincers. The length of wire thus separated and confined, is now, by a movement of the machine, bent up along the sides of the square steel holder, and shaped to three edges of the square, that is, formed into a staple; and in the same way the wire is cut and bent into staples, as long as the machine is in operation.

The wire staple is held with its points or ends outwards, in close proximity to the forked piercer before described, and by another movement the staple is moved forward, its points entering the two holes previously made in the leather by the sliding fork.

While the wire staple is being thus introduced, into the leather, its legs or points are to be bent, that is, formed with a knee or angle. This is done by a bar or bed which bears up against the under side of the wire staple when it has been passed half way into the holes in the leather, and another bar above it being brought down behind the staple, bends it over the resisting bar to the angle required, forming the knee in each leg. A pusher now acts behind the staple, and drives it home into the leather, which completes the operation.

In this manner a sheet of card cometimes called card clothing is made, of the kind usually employed for carding wool, cotton or other fibrous materials. The wire staples are set in the leather, sometimes in lines crossing the sheets, which is called ribbed, or in oblique lines, called twilled, which variations are produced by the positions of the notches or step on the periphery of the cam or indented wheel, which shifts the guide rollers, that hold the leather fillet as described.

CARDING. In the manufacture of cotton, the carding process is designed to disentangle the fibres of

the cotton, and lay them lengthwise, instead of doubled up as they usually are in leaving the pickers or blowing machiues ; this is effected by the mutual action of two opposite surfaces of card clothing in the carding engine. This machine consists of one or more cylinders, covered with card leather or clothing, and a set of plane surfaces similarly covered, made to work against each other, but so that their points do not come into absolute contact.

In cotton mills making fine work, two carding machines are always used; one coarser called a breaker, which forms a broad thin lap, which is then passed through the finisher which has finer teeth.

Fig. 779 is a sectional elevation of a carding machine of English construction, and 780 a side elevation of the same machine, (by a mistake in the drawing reversed) showing the driving pullies and geers; *a* is one of two upright slots which receive the ends of the lap rolls; the circumference of the lap rests upon a roller *b*, which assists the unfolding of the lap. The fluted cylinders *e*, receive the lap which passes over the table at *c*; these fluted rollers are $1\frac{1}{8}$ inch diameter, and have 28 flutes in their circumference ; *g* is a weight hung upon the axis of the upper fluted roller, causing it to press upon the under one ; *f* is the main card drum, *g g g* the flat top cards, *h* the small cylinder card for stripping off the cotton, called the *doffer* ; *i* the doffer knife or comb for stripping the fleecy web from the doffer, operated by the lever mechanism, *k*, *l*, *g*, *m*.

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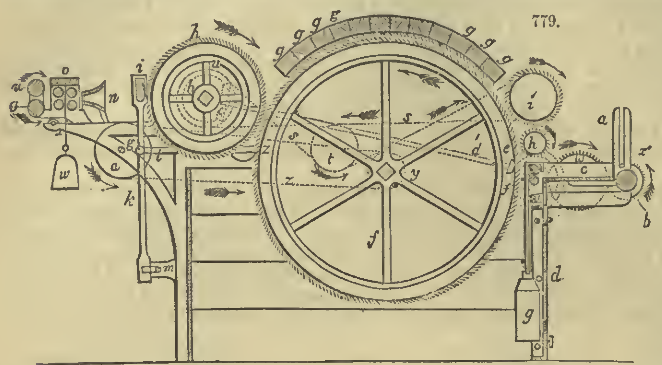

The flat top cards, are long narrow strips of wood lined on their under surfaces with card clothing, they are attached over the main card drum by holes at each end, which fit down upon strong iron pins upon the arched cast-iron frame of the engine, as shown at *k k*, fig. 780 ; *l l* are screws which come in

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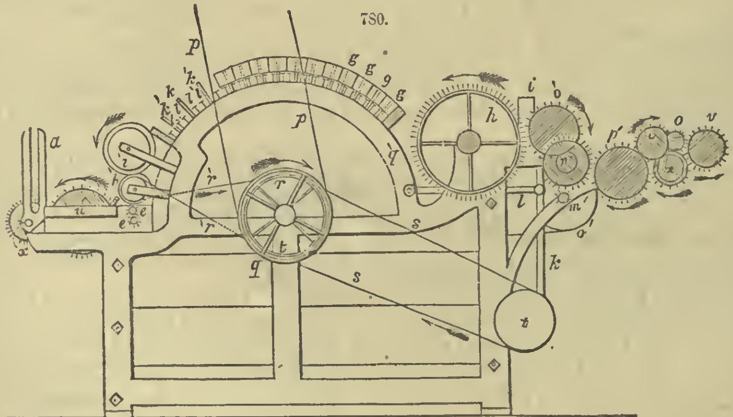

contact with the bottom of the holes, and by these the pins are lengthened or shortened so as to adjust the tops very truly with the drum teeth revolving beneath them ; *h*, is a small cylinder, and *i* another cylinder, both of which are covered from end to end with narrow strips of card laid on spirally. The main drum is covered with card clothing in strips laid to the axis, with smooth leather borders between. The arrows in the figure show the direction in which the cylinders revolve.

The card end or fleece taken off the doffer *h*, by the crank and comb *i k m*, passes through a tin plate or brass funnel *n*, (fig 779,) by which it is condensed into a riband, which is then passed through the drawing rollers *o*, thence it is conducted by the rollers *u v* into tin cans placed below.

The band, *p p*, (fig. 780,) drives by means of the pulley *g* the drum *f*, (fig. 779,) with a velocity of from 120 to 140 revolutions per minute. The drawing rollers *o and u v*, are operated by the system of geering shown at *p′ o* and *v*, fig. 780, to which motion is imparted by the pinion *m′* on the axis of the pulley *a′* belted to the pulley *y* on the main drum shaft.

The wheel *h* on the doffer cylinder also derives its motion from the pinion *m′* by means of the pinion *n′* and intermediate wheel *o′*. The wheel *n′* turns by the carrier wheel *p′* a wheel *x*, whose axis is shown at *x* (fig. 779.) The axis of *x* carries, towards the middle *f* the engine a very broad wheel, which is represented by a dotted circle. The toothed wheel *v* of the smooth roller *v′*, and the two toothed wheels *o o.* of the under rollers *o o.* work into this broad wheel. The large runner *i* is driven from the

main drum pulley, by the band s', and the pulley u' fig. 779. The motion of the fluted rollers e which feed in the lap, is effected by means of a bevel wheel b' on the end of the doffer, which works into a similar wheel c' on the oblique axis d', (shown by dotted lines) of the pinion e' upon the lower end of the same axis which turns the wheel f', upon the under feed roller. The lever mechanism of the stripper knife i, is operated by the pulley t driven by the band s from the pulley r on the drum shaft. The operation of the cylinders h and i, will be understood by comparing their speed with one another and with that of the main drum, and taking into account the direction in which the carding cylinders revolve.

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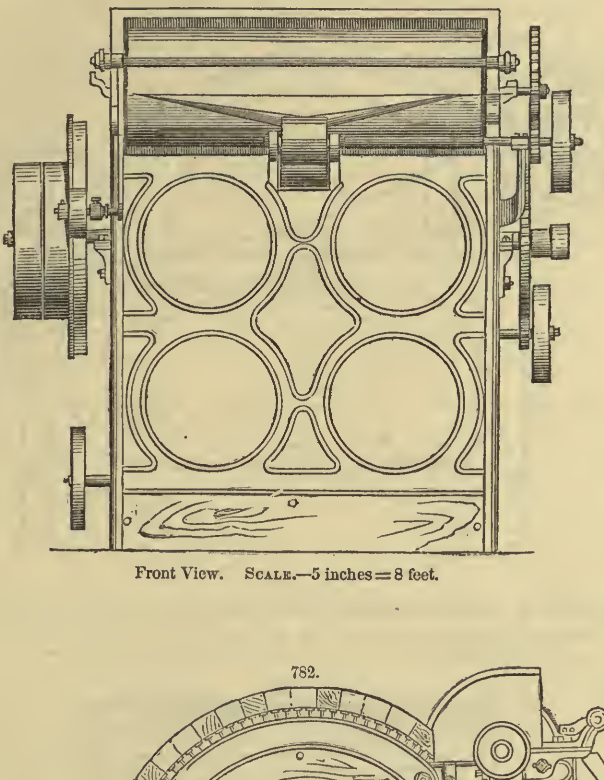

Front View. Scale.—5 inches = 8 feet.

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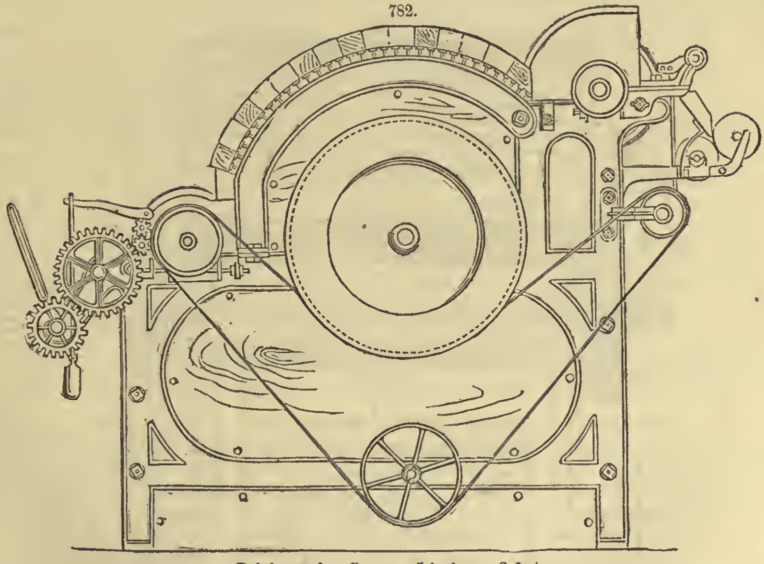

Driving-end. Scale.—5 inches = 8 feet.

The cotton which is delivered to the drum by the feed rollers is caught by the opposite teeth of the large runner i, which on account of its slow speed (98 inches per minute,) may be considered at rest with reference to the drum, and retaining the cotton in its teeth, will commence the carding or separation of the fibres. The small runner h, revolves at a much greater velocity, (5170 inches per minute,) and combs the cotton out of the teeth of the large runner i, giving it up in its turn to the swifter teeth

of the drum, which brings it in contact with the teeth of the top cards, by which the fibres are finally arranged in their proper position. The quantity of cotton, or the thickness of the lap, the velocity of the cards, and of the drawing rollers, must be carefully adjusted to the number or size of the yarn intended to be spun.

Figs. 781-2-3-4, represent the front, sides, and rear elevation of a carding machine as manufactured at the machine-shop, Lowell, Mass., intended for a BREAKER card; the FINISHERS are in general constructed with more top cards.

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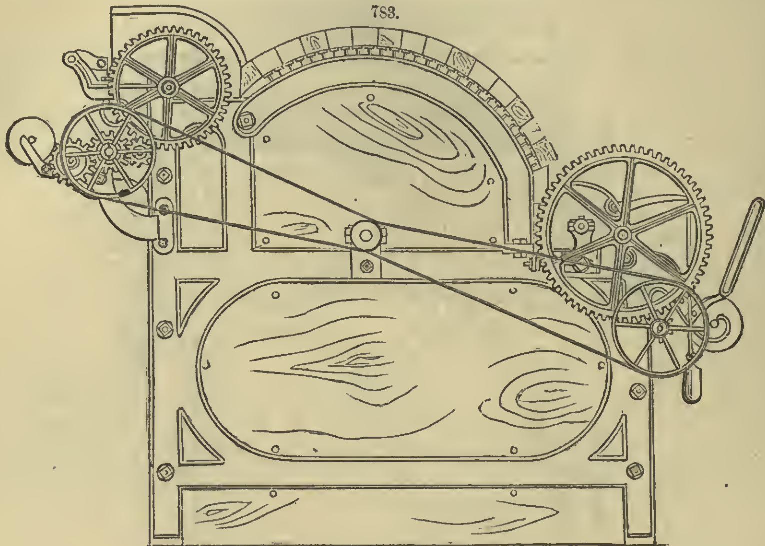

Gear-end. SCALE.—5 inches = 8 feet.

There are but few mills in the United States that use single carding; the greater part use Breakers and Finishers, even those that manufacture the coarsest goods. In the Eastern district the general breadth of the cards is 37 inches, and diameter of main cylinder 36″; doffing cylinder 13″; feeding rollers $1\frac{1}{4}$″

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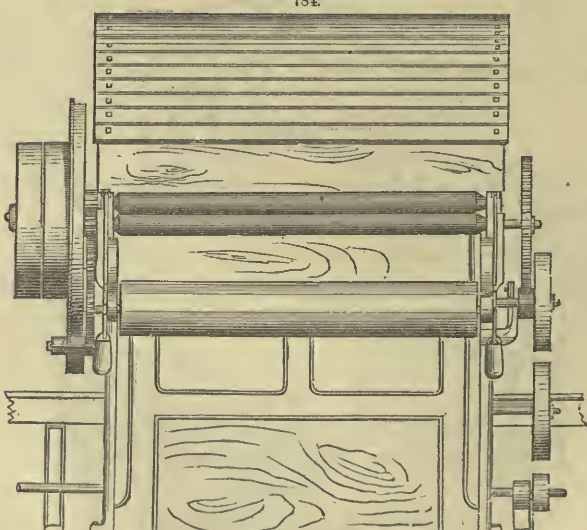


Back View. SCALE.—5 inches = 8 feet.

The main cylinders are made of cast-iron, and covered with broad filleting, instead of sheets. The average speed of the main cylinders is about 100 revolutions per minute. In the Rhode Island district the cards are made of various breadths, from 18 to 36 inches, and are principally wooden cylinders covered with sheets. In the Southern district the general breadth of the cards is 24″ to 30″. There

are some cast-iron cylinders covered with sheets. The average speed of the cylinders in the two latter districts is 110 revolutions a minute, and diameter 36 inches. The stripping is performed by two persons; one, the *top-stripper*, begins at the first cards in the series, and strips every second top all over; that is, the 1st, 3d, 5th, 7th, 9th, 11th, &c., until the whole of the tops are stripped in two or three courses. The cylinder is also stripped by the cylinder-stripper, thus keeping up a constant system of stripping all the time the machinery is in motion.

For the purpose of *sharpening the teeth*, when a carding-engine is first filled with new sheets, fillets, &c. the cylinders are put in motion the right way, and a light emery-board, about 4 inches broad, is traversed over the top of the cylinders, with a very delicate hand; this is called facing up the teeth, because the points of the wires are running against the board, and is intended to cut down any single wires that may be too long. After running the cylinders in this way about fifteen minutes, their motions are reversed, and are mounted on the main and doffing cylinders; these are denominated the fast-grinders, and which, after being properly set, are caused to revolve in an opposite direction to the card cylinders. This operation is continued until the whole of the teeth on both cylinders are ground down to one uniform length; but during the process of grinding, the emery cylinders are made to traverse a little each way, so as to grind the wires to a round point, and prevent them from being hooked. The cards are then dressed up—first with a brush dusted with chalk, and then with emery-boards, called strickles; this latter process is called sharpening, and is continued daily to the *Breakers*, and every second day to the *Finishers*. The *fast-grinders* are not applied above once a year, or only when the cylinders on some parts of the surface have become higher than on the other parts, or, technically, "*off the truth*." By this method of grinding the cards when necessary, and sharpening them every working day, they are always in good order, and consequently produce more perfect work: also, when the practice of sharpening is continued daily, it can be done in much less time; two men can easily sharpen thirty carding-engines in the space of four hours. The card-belts being all fitted with buckles, no time is lost in making them long or short, for the purpose of reversing the motion of the cylinders. The tops are also brushed out and sharpened once a week.

CARPET SHAKING MACHINE. A machine is in successful operation in the upper part of the city* for beating and brushing dusty carpets. The machine consists of a wooden frame 22 feet long, 8 feet high and 5 feet wide, built of 2000 superficial feet of yellow pine timber. It is driven by steam of two horse power, and cleanses the largest carpet in 15 minutes, by running it through the machine twice. Four heavy carpets can be operated on at one time. If the carpet is very dirty, large, and heavy, it takes a few minutes longer, and 2000 yards of carpet can be beaten per day. The carpet to be operated upon is attached to a canvas which is already tacked to and wound upon a windlass; the machine is put in motion and the carpet passes under a set of wooden flails attached to steel springs, which thoroughly beat it as it ascends. The beating is performed by the middle of the sticks, obviating the risk of tearing the fabric; in hand work, on the contrary, the carpet is struck with the end of the rod used, and this is liable to start the warp. When the carpet passes near the top of the machine, it is operated upon by 56 corn brooms of large size, which revolve rapidly on a shaft, and sweep the carpet as it moves by them slowly, on its way over another roller at the top of the machine, whence it passes to another cylinder and is wound up. If necessary, the carpet can be run back again over the four rollers, and so on. It takes two men to watch the machine and engine. The flail-like sticks that beat the carpet are acted upon by cast-iron flyers, and a number of taut ropes that react.

CARS. See "Rolling Stock" of Railroads.

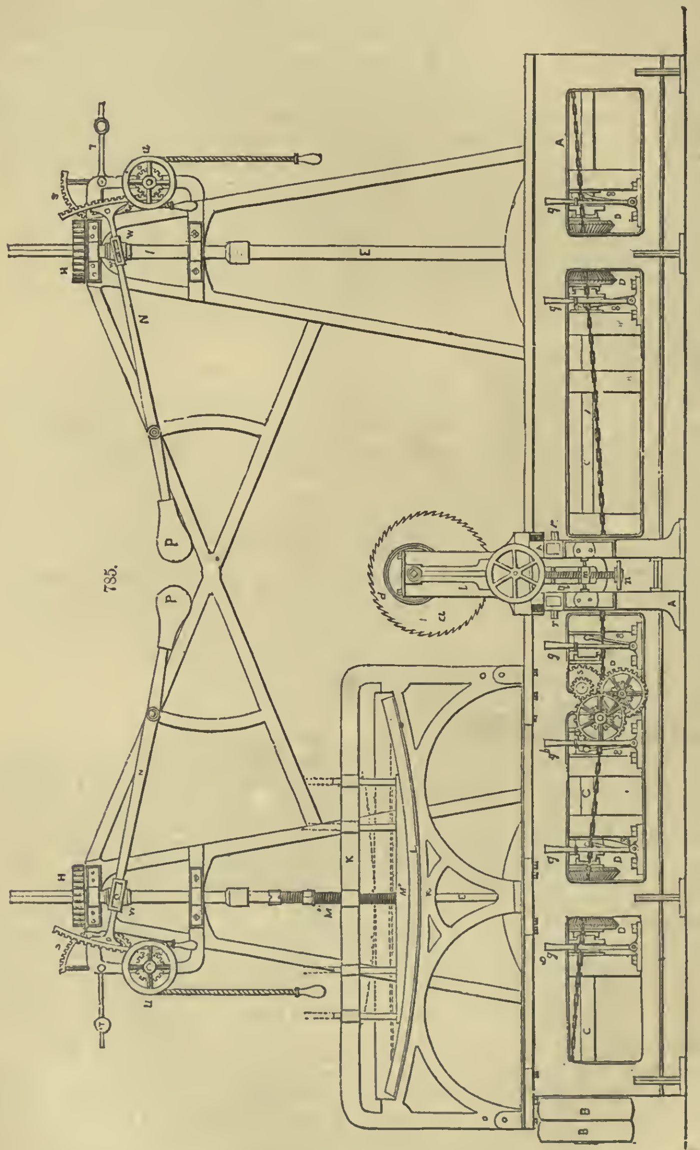
CASE HARDENING. See Tempering.

CASK-MAKING MACHINERY—Rosenborg and Montgomery's *patent*. The patent of Messrs. Rosenborg and Montgomery comprehends a number of processes or mechanical arrangements relating to cask-making, all of which are more or less new and valuable. First, there is a method of sawing wood into pieces or blanks suitable for staves; second, a method of converting these blanks into staves; third, one for combining the staves into casks; and fourth, an apparatus for drilling the holes or sockets in the beads of casks for the reception of the dowels necessary for keeping the parts together. It is the machine comprehended under the second of these heads which has particularly struck us for its ingenuity, and which we here propose to describe. A simple statement of the problem of which it is the practical solution will suffice to convey to the reader a clear idea of the difficulties which the inventors had to overcome. The problem was this:—To take any given number of flat rectangular staves, and so shape the whole at one operation that when built up together into a cask, they shall every one have the exact bevel, bulge, and taper, which is requisite for the formation of the cask. The new machinery by which Messrs. Rosenborg and Montgomery have accomplished this rare combination of difficult achievements is represented in the accompanying figures, of which the following is their own description:

Fig. 4005 represents a front elevation, Fig. 4006 a back elevation, Fig. 4007 an end view, and Fig. 4008 a cross section of this machine. A is the framework; B B the loose and fast-driving pulleys on the main-shaft C; D D bevel-wheels which run loose on the shaft; E E vertical shafts which revolve at right angles to the main-shaft C, and are put in motion by bevel-wheels F F. G and H are spur-wheels which communicate motion to the vertical shafts I I at the front of the machine; K is a frame which slides on the framework A, and carries the blank which is to be formed into a stave. M^1 is a pressing-block, which is made of a convex form on its under surface, corresponding exactly with the interior curve of the intended stave. M^2 is a screw which is passed through the top bar of the frame K, and acts upon the block M^1; N is a lever centred at n, which has a toothed segment O on one end, and a counter-weight P on the other. Q is a pinion which works into the toothed segment O; R (see Fig. 4007, the end view of the machine) is another pinion on the same shaft as Q, which works into another toothed segment S, and thereby gives motion to the tumbler T. U is a cord-wheel, by means

* Bourne & Emery, 139 and 144 Bank street.

of which motion is given to the toothed segment O and lever N, and also to the tumbler T. V is a loose socket on the vertical shaft I, which socket is kept in its place by means of two collars W W, and has two pins projecting from it at right angles, which work through slots in the eye-piece X of the lever N, which eye-piece fits on to the shaft I. Y is a drum which carries the chain Z over the rollers 1, and being fastened to the sliding-frame K, gives motion to the same. The chain-drum Y receives its motion through the bevel-wheel 2, which works into the bevel-wheels D^1 D^1 on the main-shaft C on the other end of the shaft which carries the bevel-wheel 2 is a pinion 3, which works into the spur wheel 4, to which spur-wheel is attached the pinion 5, which works into the spur-wheel 6 on the shaft



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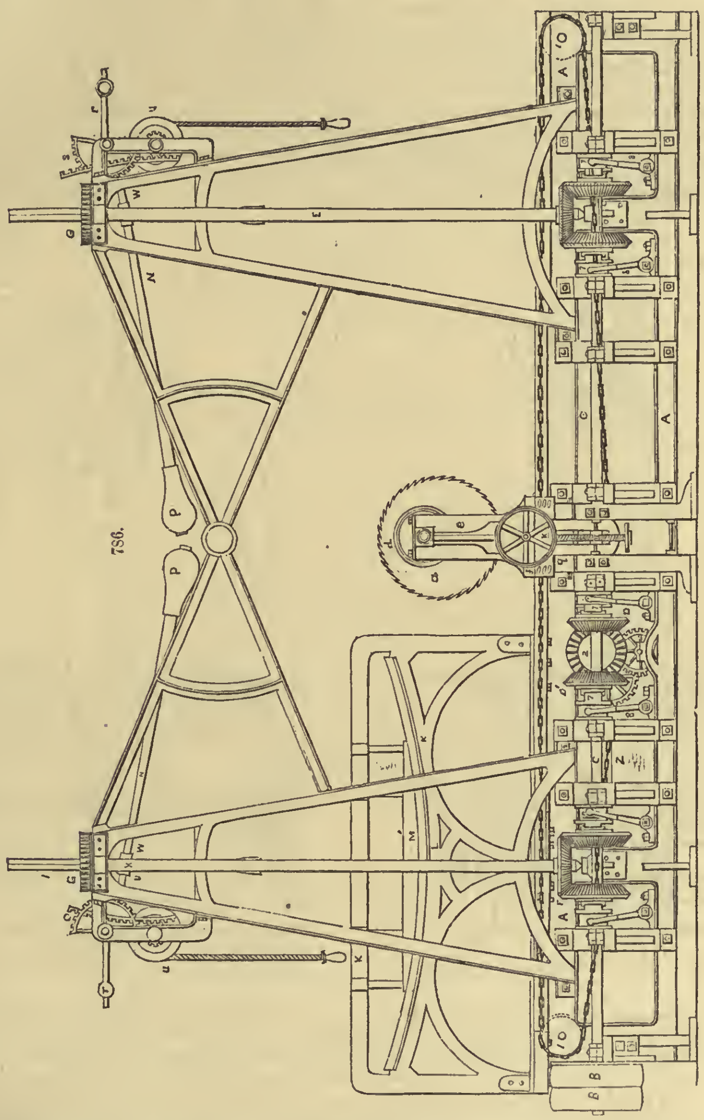
of the chain-drum Y. 7 7 are clutch-boxes which slide on keys on the main-shaft C, and are worked by forked levers 8 8, which again are actuated by the handles 9 9, as seen in the front view of the machine, Fig. 4005. *a a* are circular saws which are fixed to the shafts *b b*, to which shafts motion is given by the strap-pulleys; *c d* are loose strap-pulleys on the same shafts *b b*. The shafts *b b* are mounted in frames *e e*, which are made to slide on the plates *f* by means of V-champs; *g g* are screws by which sliding motion is given to the frames *e*, the screws working in the nuts *h* affixed to the frames *e e*. The spindles of the screws *g g* are mounted on the plates *f f*, and carry at their outer ends hand-wheels *i i*; *k k* are swivel-joints fastened underneath the plates *f f*; *l l* are screws, the upper and plain ends of

which work into the swivels $k\ k$, and are so kept in their places by means of pins which fit into circular grooves cut in the ends thereof. The screws $l\ l$ are also tapped through a swivel-nut m, which has its bearings in plummer-blocks attached to the frame A, and have hand-wheels $n\ n$ at their lower ends. The plates $f\ f$ have lugs $o\ o$ fastened on their inner ends, which lugs work upon shafts $p\ p$, and so form centres for the circular motion of the plates $f\ f$. The plates $f\ f$ are provided also underneath with guides $q\ q$, which work tight in the framework A. The guides $q\ q$ have two screws $r\ r$ tapped into them on each side, which work through slots $s\ s$ in the framework A. The machine is worked in the following manner:



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The sliding-frame K being placed at one end of the machine, so that the screw M^2 is in the same vertical line with the shaft I, the pressing-block M^1 being raised close under the top of the frame K, (see dotted lines in Fig. 4005,) the blank required to be shaped into a stave is placed in the frame K. The handle 9^a is moved towards the left, so as to couple the clutch-box 7 with one of the bevel-wheels D. Motion being communicated to the vertical shaft I, in the front of the machine the man takes hold of the cord-handle nearest to the shaft I, and turns the cord-wheel U. By doing so, the vertical shaft I will be lowered down upon the square part of the screw M^2, (the socket of the vertical shaft I fitting over the square top of the screw,) and the tumbler T being moved over to the other side, will keep the shaft I close upon the screw M^2. The screw will now turn round, and thereby bring the pressing-block M^1 down upon the blank piece of wood, and by the motion being continued will press it down in a

curved position close against the bed of the frame K. The wood will now have the shape given to it which it is required to possess when put into its place as a stave in the formation of a cask. When the blank has thus been bent, the same handle 9^4 is moved towards the right, whereby the clutch-box 7 is disengaged from the bevel-wheel D. The motion of the screw is thus stopped, and the workman, by taking hold of the corded handle farthest from the shaft I, causes the cord-wheel U to turn round, by means of which the shaft I is disengaged from the screw M^2, and raised to its former position. The workman now takes hold of the handle 9^5, which couples the chain motion, and by moving that handle so as to bring the corresponding clutch-box into geer, the chain-drum Y will turn round, by means of which the slide K will be put in motion. The circular saws *a a*, being always in motion when this machine is at work, the blank will now be brought into contact with them, and both the sides of the blank will thereby be cut as the slide continues to move betwixt the saws *a a*. When the slide K arrives at the other end of the machine, the handle 9^5 for the chain-coupling is moved by the workman, so as to detach the clutch-box from the bevel-wheel D, and thereby stop the motion of the slide, which will now be in the same position at this end of the machine as it was before at the other end, that is to say, the screw M^2 will be in the same line with the vertical shaft I at this end of the machine. One of the handles 9^3 is now moved by the workman putting the shaft I at this end of the machine in motion in the reverse direction, which being done, the workman takes hold of the corded handle nearest to the shaft I, and by twining round the cord-wheel U, causes the shaft I to descend upon the screw M^2, and thereby puts that screw in motion, which causes the pressing-block M^1 to rise up under the top of the frame

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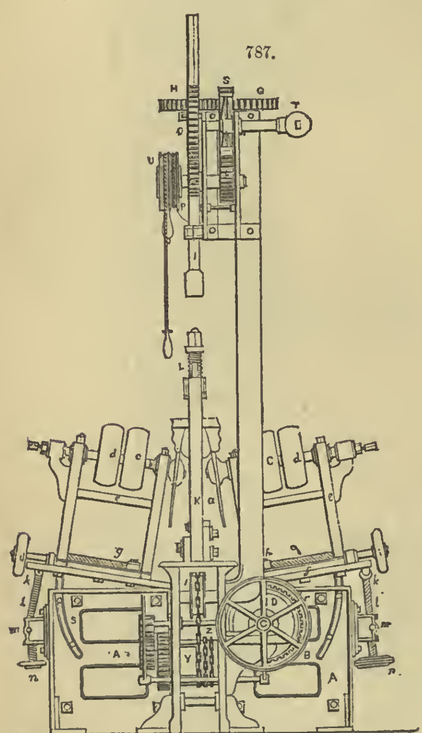

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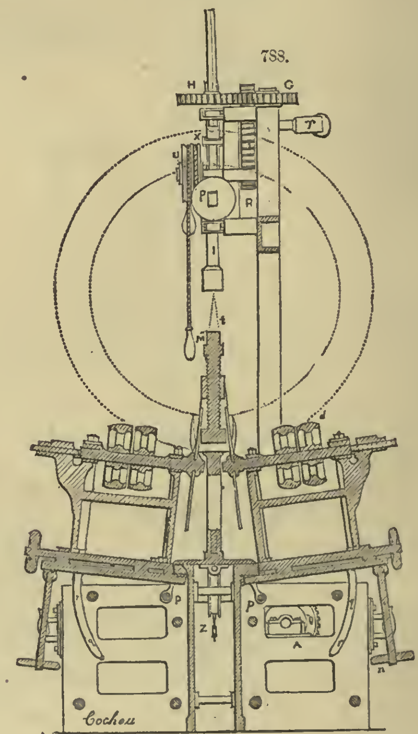


K. The workman now stops the motion of the shaft I, but he does not disengage that shaft from the screw M^2. The stave, being now completed, is removed from the frame K, a fresh blank put in, and the preceding operation repeated, but in the reverse direction of the machine. In order to enable the workman to vary the width of the cut staves, and also to enable him to alter the position of the saws to cut the various bevels required for different-sized casks, the saws are adjusted in the following manner:—Having determined upon the required width of the stave, he moves the hand-wheels *i i*, and by means of the screw *g g*, adjusts the frames *e e*, and the saws *a a*, to the requisite distance from the central line of the framework K. Having done this, he moves round the hand-wheels *n n*, on the screws *l l*, and thereby causes the outer ends of the plates *f f* to rise or fall, in order to place the saws *a a* in a position to form the radii, or nearly so, of the circle of the cask to be made, (see the dotted lines *t t*, Fig. 4008) He now tightens the bolts *r r* on both sides of the guides *q q*, outside the frame A, whereby the angular position of the plates *f f* is secured. With such modifications as will readily suggest themselves to a competent workman, the blank in its longitudinally curved state may be submitted to a circular saw-bench, to a planing or other cutting machine, or to suitable cutting-tools, in order to produce a stave with the bevel bulge and taper requisite for its formation into a cask; a stave may thus be formed either by machine or hand-power, and one or both sides may be completed in one operation.

The improved machinery of Messrs. Rosenborg and Montgomery has not been as yet many months in operation, but already a very considerable number of casks of nearly all descriptions have been manufactured by them; viz., oil-butts for the fisheries, water-butts for emigrants, rum puncheons, sherry pipes, hogsheads, and quarter-casks, beer hogsheads, and barrels for exportation and inland trade, spirit puncheons, &c., &c. Of these, some have been sent to the Hudson Bay Company's settlements, some to Spain, to the West Indies, to the coast of Africa, to the East Indies, to Australia, and to New Zealand.

All these casks have given the utmost satisfaction, with the exception of a very few of those first put together, before the machinery was in perfect working order. Certainly casks cannot be made by hand to equal those which were turned out the other day. The mathematical correctness with which the staves are shaped (or "jointed," as the coopers call it) by these machines, gives much greater strength and tightness to the casks than ever has been witnessed before. The hand-cooper's *art*, in giving form to the stave, is a very difficult one, and requires long practice. He works entirely by measure of the eye; but however well instructed he may have been—however expert he may have become in hitting angles—still he cuts away to a certain extent at random, and it is therefore impossible that he can attain to that accuracy which is necessary to make a stave *a perfect part of a cask.* Besides, casks of different shapes and sizes require staves of different forms, depending upon the greater or lesser "bilge" and length, by which the curvature of the lines of the staves must be determined. Another most difficult and important matter to be attended to is *the bevelling of the edges.* As the cask varies in diameter from the middle or highest point of the bilge to the end or "head," so must the bevel of the edges of each stave vary accordingly, in order to produce a good or "tight joint," or to make the stave fit well in its place. It is no doubt this latter circumstance which has presented to inventors hitherto the principal difficulty in the way of constructing machines for jointing staves. By the machinery of Messrs. Rosenborg and Montgomery, the curvature of the lines, as well as the varied bevel of the edges, are given to the staves with unerring correctness, whatever may be the shapes and sizes of the casks.

CAST-IRON. See Iron.

CASTINGS, *how to make fine.* See Details of Engines, and Casting and Founding.

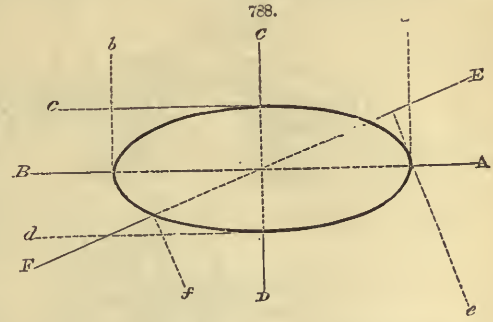
CASTING AND FOUNDING. We are indebted to the fusibility of the metals for the power of giving them, with great facility and perfection, any required form, by pouring them, whilst in the fluid state, into moulds of various kinds, of which the castings become, in general, the exact counterparts. This property is of great value.

Some few objects are cast in open moulds, so that the upper surface of the fluid metal assumes the horizontal position the same as other liquids, as in casting ingots, flat plates, and some few other objects; but in general the metals are cast in close moulds, so that it becomes necessary to provide one or more apertures or *ingates* for pouring in the metal, and for allowing the escape of the air which previously filled the moulds.

When these moulds are made of metal, they must be sufficiently hot not to chill or solidify the fluid metal before it has time to adapt itself thoroughly to every part of the mould; and when the moulds are made of earthy matters, although moisture is essential to their formation, little or none should remain at the time they are filled.

The earthen moulds must be also sufficiently pervious to air, that any vapor or gases which may be formed, either at the moment of pouring in the metal or during its solidification, may have free vent to escape; otherwise, if these gases are rapidly formed, there is great danger of the metal being driven out of the mould with a violent explosion, or when more slowly formed and locked up without sufficient freedom for escape, the casting will be said to be *blown*, as some of the bubbles of air will displace the fluid metal and render it spongy or porous. It not unfrequently happens that castings which appear externally good and sound, are full of hidden defects, because the surface being first cooled, the bubbles of air will attempt to break their way through the central and still soft parts of the casting.

788.



The explanatory diagram, Fig. 788, is intended to elucidate some of the circumstances concerning the construction of moulds, which in the greater number of cases are made only in two parts, but in other cases are divided into several. The figure to be moulded is supposed to be a rod of elliptical section, the mould for which might be divided into two parts through the line A B, because no part of the figure projects beyond the lines *a b*, drawn from the margin of the model at right angles to the line of division, and in which direction the half of the mould would be removed or *lifted;* the model could be afterwards drawn out from the second half of the mould in a similar manner.

The mould could be also parted upon the line C D, because in that direction likewise, no part of the model extends beyond the lines *c d*, which show the direction in which the mould would be then lifted.

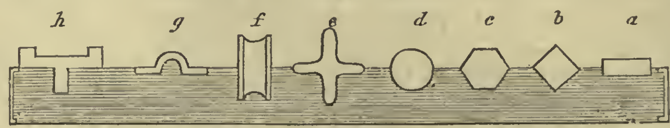
The mould, however complex, could be also parted either upon A B or upon C D, provided no part of the model outstepped the rectangle formed by the dotted lines *b c*, or was undercut.

But, considering the figure 788 to be turned bottom upwards, and with the line E F horizontal, the

removal of the entire half of the mould upon the lines *c f* would be impossible, because in raising the mould perpendicularly to E F, that portion of the mould situated within the one perpendicular *e*, would catch against the overhanging part of the oval towards A. Were the mould of metal, and therefore rigid, it would be entirely locked fast, or it would not "*deliver;*" were the mould of sand, and therefore yielding, it would break and leave behind that part between A and E which caused the obstruction. Consequently, in such a case, the mould would be made with a small loose part between A and E, so that when the principal portion, from A to F, had been lifted perpendicularly or in the direction of the line *e*, the small undercut piece A to E might be withdrawn *sidewise*, on which account it would be designated by the iron-founder a *drawback*, by the brass-founder a *false core.*

All the patterns in the mould, Fig. 789, could be extracted from each half of the mould, because none of them encroach beyond the perpendicular line, or that in which the mould is lifted; *a* and *b* could be laid in exactly upon the diagonal, or upon one flat side, or partly imbedded; and in like manner *f g h* might be sunk more or less into the mould, their sides being perpendicular; but the patterns

789.



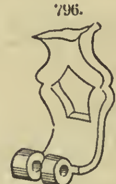
790.

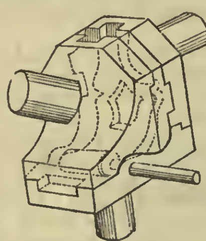
in Fig. 790 being undercut, the division of the mould into two parts *only* would be impracticable, and false cores or subdivisions would be required in the manner represented, the construction of which will be hereafter detailed.

Extending these same views to a more complex object, such as a bust, it will be conceived that the mould must be divided into so many pieces, that none of them will be required to embrace any

795.

796.





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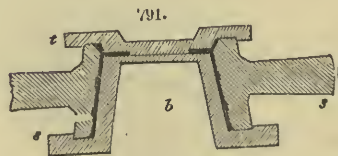

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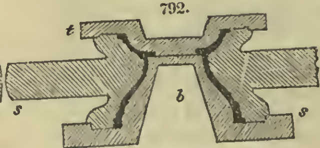

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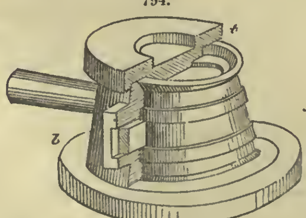

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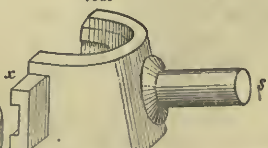


overhanging part of the figure. For instance, were it attempted to mould a human head so that the parting might pass through the central line of the face and down the back: the two halves could not be separated if they were made each in a single piece, as the inner angles of the eyes, the spaces behind the ears, and the curls of the hair would obstruct it, and the head could be only thus moulded

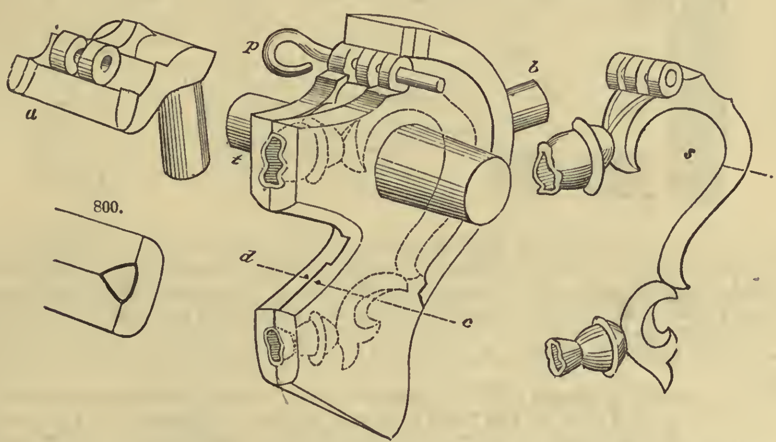
by making false cores or loose pieces at these particular places, in the manner illustrated by the former figures. These, would require to be accurately adapted to the surrounding parts by pins, or contrivances to ensure their retaking their true positions. These remarks, however, are only advanced by way of general illustration, as figure-casting is the most refined part of the art of moulding.

Metal moulds are employed for many works in the easily-fused metals, which are required to be produced in large quantities, and with great similitude and economy: the examination of which moulds will serve to demonstrate many of the points of construction and proceeding. Thus the common bullet-mould is made like a pair of pliers, the jaws of which are conjointly pierced with a hole or passage leading into a spherical cavity; the aperture is equally divided between the two halves of the mould, so that in fact the division is truly upon the diametrical line both of the sphere and the runner, or the largest part of each; otherwise the pliers could not be opened to remove the bullet when cast. Iron shot for great guns are likewise cast in iron moulds, by which they also possess great accuracy of form and size.

Figs. 791 to 794 represent the moulds for casting pewter inkstands. These moulds are a little more complex, and are each made in four parts; the black portions represent the sections of the inkstands to be cast. The moulds each consist of a top-piece or *cap t*, a bottom or *core b*, and two sides or *cottles s s*. In Fig. 794 the one side is removed, in order to expose the castings, and the top-piece *t* is supposed to be sawn through to make the whole more distinct. It will be seen the top and bottom parts have each a rebate like the lid of a snuffbox, which embrace the external edges of the two side-pieces *s s*, and the latter divide, as in the bullet-mould, exactly upon the diametrical line of the inkstand, which in a circular object is, of course, the largest part; the positions of the parts are therefore strictly maintained.

When the mould has been put together, laid upon its side, and filled through *x* the ingate, or as it is technically called, the *tedge*, it is allowed to stand about a minute or two, and then the top *t* is knocked off by one or two light blows of a pewter mallet; the mould is then held in the hand, and the bottom part or core is knocked out of the casting by the edge; lastly, the two sides are pulled asunder by their handles, and the casting is removed from the one in which it happens to stick fast; but it requires cautious handling not to break it. The face of the mould is slightly *coated* with red ochre and white of egg, to prevent the casting adhering to the same, and to give the works a better face. The first few castings are generally spoiled, until in fact the mould becomes properly warmed.

799. 798. 797.



Most of the works made in the very useful material, pewter, are cast in gun-metal moulds, which require much skill in their construction; thus, a pewter tankard, with a hinged cover and spout, consists of six pieces, every one of which requires a different mould. Thus:—

1. The body has a mould in four parts, like that for the inkstand, but it is filled in the erect position through two ingates, which are made through the top-piece *t* of the mould.
2. The bottom requires a mould in two parts, and is poured at the edge.
3. The cover is cast in the same manner; and thus far the moulds are all made in the lathe, in which useful machine these castings are also finished before being soldered together.
4. The spout requires a mould in two parts.
5. The piece, Fig. 796, by which the cover is hinged to the handle, requires a much more complex mould, which divides in four parts, as shown in Fig. 795, and much resembles, except in external form, the remaining mould: namely,
6. For the handle, which mould, like the last, consists of four pieces, fitted together with various ears and projections. They are represented in their relative positions in Fig. 798, with the exception of the piece *a*, Fig. 799, which is detached and shown bottom upwards. Fig. 797 shows the pewter handle separately, with the three knuckles for joining on the cover; and on reference to Fig. 798, of the five parts through which the pin *p* is thrust, the two external pieces belong respectively to the sides *c* and *d* of the mould; the others are parts of the casting, and the two hollows are formed by the two solid knuckles fixed to the detached piece of the mould *a*, Fig. 799. At the time of pouring, the pin *p* serves

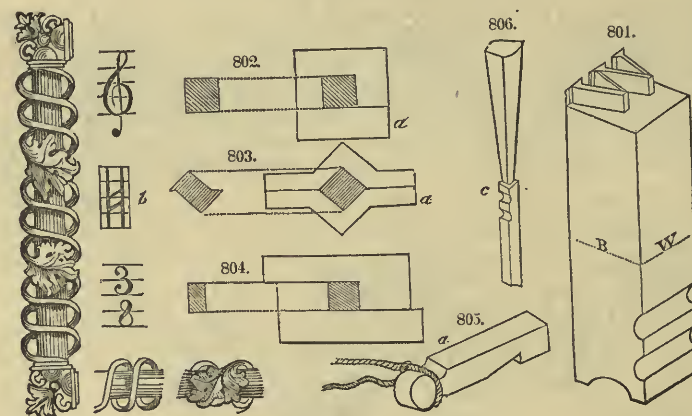
to connect the three parts *a c d* together, and also to form the hole in the casting for the pin of the joint.

Fig. 800 shows the section of the mould upon the dotted line *s*. By this it will be seen the handle is cast hollow, as almost immediately the mould has been filled through *t*, all but the thin external shell is poured out again, and the weight is reduced to less than half. To extract the handle, the pin *p* is first twisted out; then the joint-piece *a* is removed; next the back-piece *b*; and lastly, the two sides *c d* are pulled asunder.

Tin or pewter bearings for locomotive carriages have been cast in appropriate metal moulds; and such materials are very useful to the mechanist for many temporary purposes, such as collars, bearings, screws, and nuts, either for difficult positions, or where no screw-tap is at hand and the resistance is moderate; in such cases the parts of the machine constitute one portion of the mould, the apertures being closed with moist loam. The processes are most successful when the parts can be made warm and the clay is nearly dry.

The most important, exact, and interesting example of casting in metallic moulds is that of type-founding, the description of which, as well as drawings of the mould, have been repeatedly given; some of the peculiarities only of this art, will be therefore noticed. Each complete set of types consists of five alphabets, A, ᴀ, a, *A*, *a*, besides many other characters, in all about two hundred, and which are required to be most strictly alike in every respect, except in *device* and *width;* the width is the greatest for the W and M, and the least for the i and !. Every required measure of the types, (represented on an enlarged scale in Fig. 801,) is determined by the *mould alone*, and not by any after correction.

TYPE-FOUNDING.



If the moulds for the rectangular shafts of the types were made as in Figs. 802 or 803, the usual forms of square moulds, they would not admit of alteration in width, as shifting *a*, Fig. 802, would produce no change, and Fig. 803 would thereby produce the form *b*. The mould which is used, is made in two L-formed parts, as in Fig. 804; whence it follows that shifting the part *a* to the right or left, increases or decreases the width of the type without interfering with its thickness, or as it is technically called, its *body*, (B, Fig. 801;) the width, W, is adjusted by a piece called the *register*, fixed at the bottom of the mould.

The device is changed by placing across the bottom of the mould one of the two hundred little pieces of copper, Fig. 805, called *matrices*, into which the face of the letter is impressed by very beautifully-formed punches. The length of the letter is determined by a contraction at the upper part of the mould, as shown at *c*, Fig. 806, which represents the type as it leaves the mould; the metal is poured with a *jerk*, to make a sharp impression of the matrix,—the mould, which is held in the left hand, and the ladle in the right, being jerked simultaneously upwards, at the moment of filling the mould, and without which the face of the type would be rounded and quite imperfect. The *breaks c*, or the runners of the types are first broken off, and after a slight correction of the sides, the hollows or channels in the feet are planed out of a whole column of them, fixed between bars of wood, without touching the square shoulders which determine the lengths of the types, and are left as originally cast.

In some types with a large face and much detail, such as the illustrations given above, the motion of the hand is barely sufficient to give the momentum required to throw the metal into the matrix, and produce a clean, sharp impression. A machine is then used, which may be compared to a small forcing-pump, by which the mould is filled with the fluid metal; but from the greater difficulty of allowing the air to escape, such types are in general considerably more unsound in the shaft or body; so that an equal bulk of them only weigh about three-fourths as much as types cast in the ordinary way by hand, and which for general purposes is preferable and more economical.

Some other variations are resorted to in type-founding; sometimes the mould is filled at twice, at other times the faces of the types are *dabbed*, (the *clichée* process;) many of the large types and ornaments are stereotyped, and either soldered to metal bodies, or fixed by nails to those of wood. The music type, and ornamental borders and dashes, display much very curious power of combination.

The *clichée* process is rather stamping than casting. The melted alloy is placed in a *paper* tray, and

stirred with a card until it assumes the pasty condition. The *metal* die, or mould, is then "dabbed" upon the soft metal, as in sealing a letter, but with a little more of sluggish force.

Plaster of Paris Moulds, and Sand Moulds.—Other examples of metallic moulds might be given, but there are far more frequent cases in which one single casting is alone required; or else the number is so small, or the pieces themselves are so large or peculiar, that the construction of metal moulds would be found almost or quite impracticable, even without reference to an equally fatal barrier, the expense.

In making these single copies in the metals of considerable fusibility, plaster of Paris is sometimes employed: thus, after the printer has arranged the loose types into a page, and the requisite corrections have been made, a stereotype, or *solid* type, is taken of the whole as a thin sheet of metal, which serves to be printed from almost as well as the original letters; and its small cost enables the printer to retain it for future use, after the types themselves have served perhaps for a hundred similar regenerations, and are ultimately worn out.

The stereotype-founder takes a copy of the entire mass of type in plaster of Paris; this is dried in an oven, and placed *face downwards* within a cast-iron mould, like a covered box, open at the four top-corners. The mould and plaster-cast are heated to the fusing temperature of the type-metal, and gradually lowered into a pan or bath of the same by means of a crane; the hot fluid metal runs in at the corners of the mould, and raises the inverted plaster, which latter would rise entirely to the surface but for the restraint of the cover of the mould.

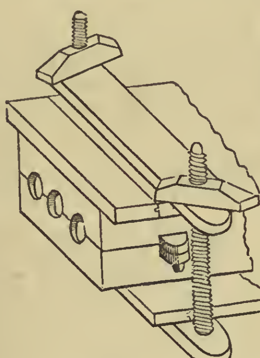
Type-metal is about eleven times as heavy as water; and if the mould be immersed four inches below the surface, it is subjected to a pressure equal to that of a column of water forty-four inches high, or of above two pounds upon every square inch.

The necessity of this arrangement is shown when a few ounces of type-metal are poured from a ladle on the face of the plaster; the metal looks like a dump, almost without any mark of the letters, whereas the stereotype-cast is nearly as sharp as the original type. The immersion fulfils the same end as the jerk of the hand-caster, or of the pump occasionally employed; and the long continuance of the mould in the fluid metal allows ample time for the air to escape in bubbles to the surface; after which the mould is raised and cooled in a vessel of water, and the plaster is mostly destroyed in its removal.

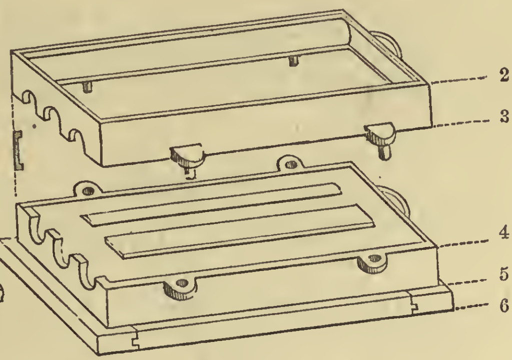
Plaster of Paris, although it may be, and frequently is used for the fusible metals, such as lead, tin, and pewter, cannot be employed alone for iron, copper, brass, and many other metals, the intense melting heats of which would calcine the material, and cause it to crumble; even the soft metals should not be very hot, or they will make the plaster of Paris blister off in flakes or dust. We must therefore seek a substitute better capable of enduring the heat, and likewise susceptible of receiving definite forms; for which purpose damp sand, with a small natural or subsequent admixture of clay or loam, is found to be perfectly adapted.

The moulding-sand cannot, however, be used without external support, and which is given by shallow iron frames, without tops or bottoms, called flasks, represented in Figs. 807 and 808. The bottom part, 4, 5, is supposed to have been rammed full of sand, and to stand upon a flat board, 6. The model of the plain flat bar which is to be cast, is now laid on the surface of the sand, that of the round bar is imbedded half way in the same, and the mould is dusted with dry parting sand.

807.



808.



The top part of the flask 2, 3, is shown still empty, and in the act of being attached to 4, 5 by its pins, which enter corresponding holes in the latter, easily but without shake: 2, 3 is also rammed full of sand, and covered with a top board, 1, not represented to avoid confusion. The mould is now opened, the models are removed, and channels are scooped out from the ends of the cavities left by the models, to the hollows or pouring-holes at the end of the flask; the parts are all replaced in the order 1 to 6, represented in Fig. 808, and the whole are fixed together by screw-clamps, so as to assume the condition of Fig. 807.

The flask is now placed almost perpendicularly beside the pouring-trough, and the metal is poured into it from the crucible; but the flask, if small, is put on the surface of the pouring or spill trough, and propped up with a short bar.

This brief sketch of the entire process of moulding and casting in sand moulds, will be now followed by some remarks in greater detail: first, on the patterns of the objects to be cast; secondly, on the conditions required in the sand; and thirdly, the process of moulding simple and solid bodies. The

section then following will be devoted to moulding cored works and figures, after which a few lines will be given upon the subject of filling the moulds.

Patterns, Moulds, and moulding simple objects.—The perfection of castings depends much on the skill of the pattern-maker, who should thoroughly understand the practice of the moulder, or he is liable to make the patterns in such a manner that they cannot be used, or at any rate be well used.

Straight-grained deal, pine, and mahogany, are the best woods for making patterns, as they stand the best: screws should be used in preference to nails, as alterations are then more easily made in the models; and glue joints, such as dovetails, tenons, and dowels, are also good as regards the after use of the saw and plane for corrections and alterations.

Foundry patterns should be always made a little taper in the parts which enter most deeply into the sand, in order to assist their removal from the same, when their purposes will not be materially interfered with by such tapering. The pattern-maker, therefore, works most of the thicknesses, and the sides or edges, both internal and external, a little out of parallel or square—perhaps as much as about one-sixteenth to one-eighth of an inch in the foot, sometimes much more.

When foundry patterns are exactly parallel, the friction of the sand against their sides is so great when they penetrate deeply, that it requires considerable force to extract them; and which violence tears down the sand, unless the patterns are much knocked about in the mould, to enlarge the space around them. This rough usage frequently injures the patterns, and causes the castings to become irregularly larger than intended, and also defective in point of shape, from the mischief sustained by the moulds; all which evils are much lessened when the patterns are made consistently taper and very smooth.

It must be distinctly and constantly borne in mind, that although patterns require all the methods, care, and skill, of good joinery or cabinet-making, they must not, like such works, be made quite square and parallel, for the reasons stated. Sharp internal angles should in general be also avoided, as they leave a sharp edge or arris in the sand, which is liable to be broken down in the removal of the pattern, or to be washed down on the entry of the metal into the mould. Either the angle of the model should be filled with wood, wax, or putty, or the sharp edges of the sand should be chamfered off with the knife or trowel. Sharp internal angles are very injudicious in respect also to the strength of castings, as they seem to denote where they will be likely to break; and more resemble carpentry than good metallic construction.

Before the patterns reach the founder's hands, all the glue that may have been used in their construction should be carefully scraped off, or it will adhere to and pull down the sand. The best way is to paint or varnish wooden patterns, so as to prevent them from absorbing moisture, as they will then hang to the sand much less, and will retain their forms much better. Whether painted or not, they deliver more freely from the mould when they are well brushed with black-lead, like a stove.

In patterns made in the lathe, exactly the same conditions are required; the parts which enter deeply into the sand should be neither exactly cylindrical nor plane surfaces, but either a little coned, or rounding, as the case may be; and the internal angles should not be turned exactly to their ultimate form, but rather filled in, or rounded, to save the breaking down of the sharp edges of the mould.

Foundry patterns are also made in metal; these are very excellent, as they are permanent; and when very small are less apt to be blown away by the bellows used for removing the loose sand and dust from the moulds. To preserve iron patterns from rusting, and to make them deliver more easily, they should be allowed to get slightly rusty, by lying one night on the damp sand; next, they should be warmed sufficiently to melt bees'-wax, which is then rubbed all over them, and in great part removed, and then polished with a hard brush when cold. Wax is also used by the founder for stopping up any little holes in the wooden patterns; whitening is likewise employed, as a quicker but less careful expedient; and very rough patterns are seared with a hot iron. The good workman, however, leaves no necessity for these corrections, and the perfection of the pattern is well repaid by the superior character of the castings.

Metal patterns frequently require to have holes tapped into them, for receiving screwed wires, by way of handles for lifting them out of the sand; and in like manner, large wooden patterns should have screwed metal plates let into them for the same purpose, or the founder is compelled to drive pointed wires into them, to serve as handles, which is an injurious practice.

The flasks or casting-boxes for containing the sand, are made of various sizes; each side is about 2 to 3 inches deep. They are poured at the edge when placed nearly vertical; but for large brass works the practice of the iron-founder is generally followed, who mostly pours his work horizontally, through a hole in the top, as will be explained. The pins of the flask should fit easily but without shake, or the two halves will shift about and cause a disagreement or slip in the casting. The tools used in making the moulds are few and simple; namely, a sieve, shovel, rammer, strike, mallet, a knife, and two or three loosening wires and little trowels, which it is unnecessary to describe.

The principal materials for making foundry-moulds are very fine sand and loam; they are found mixed in various proportions, so that the respective quantities proper for different uses cannot be well defined; but it is always judicious to employ the least quantity of loam that will suffice.* These materials are seldom used in their new or recent states for brass castings, although more so for iron; and the moulds made of fresh sand are always dried, as will be explained.

The ordinary moulds are made of the old damp sand, and they are generally poured immediately or whilst they are *green;* sometimes they are more or less dried upon the face. The old working sand is considerably less adhesive than the new, and of a dark-brown color; this arises from the brickdust, flour, and charcoal-dust, used in moulding, becoming mixed with the general stock, which therefore requires occasional additions of new sand or loam, so that when slightly moist and pressed firmly in the hand, it may form a moderately hard compact lump.

* The iron and brass founders' sand and loam used in this city are principally obtained from Long Island: and are found in great abundance in almost every state of the Union.

Red brickdust is generally used to make the partings of the mould, or to prevent the damp sand in the separate parts of the flask from adhering together.

The face of the mould which receives the metal, is generally dusted with meal-dust, or waste flour; but in large works, powdered chalk, and also wood or tan ashes, are used, from being cheaper. The moulds for the finest brass castings are faced either with charcoal, loamstone, rottenstone, or a mixture of the same: the moulds are frequently inverted and dried over a dull fire of cork shavings; or when dried, they are smoked over pitch or black resin lighted in an iron ladle.*

The cores or loose internal parts of the moulds for forming holes and recesses, are made of various proportions of new sand, loam, and horse-dung, as will be explained in treating of cored works. They all require to be thoroughly dried, and those containing horse-dung must be well burned at a red heat; this consumes the straw, and makes them porous and of a brick-red.

In making the various moulds, it becomes necessary to pursue a medium course between the conditions best suited to the formation of the mould, and those best suited to filling them with the red-hot metal, without risk of failure or accident. Thus, within certain limits, the more loam and moisture the sand contains, and the more closely it is rammed, the better will be the impression of the model; but at the same time, the moist and impervious condition of the mould would then incur the greater risk of accident, both from the moisture and from the non-escape of the air; therefore the policy, on the score of safety, is to use the sand as dry as practicable, so as to avoid the delay of after-drying, and also to keep the mould porous.

The founder, therefore, compromises the matter by using a little *facing* sand containing rather more loam, for the face of the green moulds for general work; and in those cases where much loam is used, the moulds are *thoroughly* dried by heat, which is not generally necessary with ordinary sand moulds.

The power of conducting heat is considerably less in red-hot iron than in copper and brass, and therefore the moulds for the latter require to be in a drier condition than those which may be used for iron; but in either case the presence of superfluous moisture is always attended with some danger to the individual as well as to the work.†

Another point has also to be considered: as castings contract considerably in cooling, in moulding large and slight works the face of the mould must not be too strongly rammed, nor too much dried, or its strength may exceed that of the red-hot metal, whilst in the act of shrinking. The result would be, that in contracting, the casting would be rent or torn asunder from the restraint of the mould; whereas it should have the preponderance of strength, so as to pull down the face of the sand instead of being itself destroyed. But the exact condition both of the mould and of the melted metal, must be determined by the nature of the object to be cast; matters which can be only referred to with the development of the practice of the foundry, and upon which we shall now commence.

The sand having been prepared, and the appropriate flask and boards selected, the moulder first examines every pattern separately, to determine the most appropriate way of inserting it in the flask, as explained by Fig. 789; also to see that patterns, such as *f* and *h*, therein shown, are smallest at the parts entering the most deeply into the sand, in order that they may *deliver* well. It should also be noticed whether they are perfectly smooth, and that there is no glue hanging about them, which would cause them to adhere and to pull down the moist sand.

The bottom flask, 4 and 5, Fig. 808, is placed on a board not less than an inch or two longer and wider than itself, with the face 4 downwards, and it is filled from the side 5. A small portion of the strong facing-sand is rubbed through a fine sieve; the remainder is thrown in from the trough with the shovel, and the moulder drives the whole moderately hard into the flask, either with a mallet, the handle of the spade, or other rammer; or else he jumps up by aid of the rope suspended from the ceiling, and treads the sand in with his feet. The surface is then struck off level with a straight metal bar or scraper, a little loose sand is sprinkled on the surface, upon which another board is placed, and rubbed down close.

The two boards and the flask contained between them, are then all three turned over together; this requires them to be brought to the front of the moulding-trough, so that the individual may rest his chest against them, and his fore-arms upon the edges of the top board; he then grasps the three together at the back part with his outstretched hands, and thus retained in contact, the whole are quickly turned over upon the front edge of the moulding-trough, and then slid back upon the transverse bearers or *blocks*, to the usual position.

The top board is afterwards taken off; the clean surface of moist sand, then exposed, is well dusted over with red brickdust crushed fine, and contained in a linen bag; the mouth of the bag is held in the right hand, and the bottom corner in the left, and both hands are shaken up and down together, to scatter the dry powder uniformly over the flask; a part of the loose powder is removed with the hand-bellows, and the bottom half of the mould is then ready for receiving the patterns.

The models are next arranged upon the face of the sand at 4, so as to leave space enough to prevent the parts breaking one into the other, and also for the passages by which the metal is to be introduced, and the air allowed to escape. When there are only two or three pieces to be cast, a separate runner is often made to each of them from one of the holes in the end of the flask; when several small patterns are to be moulded, they are arranged on both sides a central runner, or *ridge*, from which small passages

* The gold and silver casters frequently use a lighted link for facing their sand-moulds, and some of the type-founders' metallic moulds are smoked over a lamp: all these modes deposite a fine layer of soot upon the moulds.

† The above is the reason generally assigned for the fact, that the iron-founders may and do use their moulds with safety when sensibly more moist than is admissible for brass and copper castings. It is confirmatory of the fact, that the more dense the mould, the drier it must be; as the sand used by iron-founders is also coarser and therefore more porous than that employed by brass-founders.

lead into every section of the mould. The whole mass when poured has been compared to a great fern-leaf with its leaflets, and is usually called a *spray*.

Those patterns which are cylindrical or thick, are partly sunk in the sand, by scraping out hollow recesses with the bowl of an old copper spoon, and knocking the model into the sand with a mallet, afterwards the general surface is repaired to agreement with the *diametrical line* of the model, or its largest section, as the case may be, by means of a knife or a little piece of sheet steel, something like the worn-out blade of a dessert-knife bent up a little at the end, or else with very small trowels.

After the sand is made good to the edges of the patterns, the brickdust is again shaken over them, so that the patterns may receive a slight share as well as the general surface of the sand. The upper part of the flask 2, 3, is then fitted to the lower, or 4, 5, by the pins, and this half likewise is made up: first a little strong sand is sifted in; it is then filled up from the trough, rammed down, and struck off as before, the dry powder serving to prevent the two halves from sticking together.

In order to open the mould for the extraction of the models, a board is placed on the top of flask 2, 3, and struck smartly at different parts with the mallet; the tool is then laid aside, and the upper part of the flask and its board are lifted up *very gently and quite level;* after which it is inverted on its board, and now each of the inner faces of the mould is exposed. Should it happen that any considerable portion of the mould, say a part as large as a cent, is broken down in one piece, the *cavity* is moistened with the end of the knife, the mould is again carefully closed, and lightly struck before the removal of the patterns; it is probable on the second lifting such piece will be picked up.

The breaks are carefully repaired before the extraction of the patterns, to effect which they are driven slightly sidewise with blows of the mallet, given on a short wire or punch, so as to loosen them by enlarging the space around them; the patterns are then lifted out very carefully with the finger-nails, or sometimes a pointed wire is driven a little way into the pattern to serve as a handle to lift it by:* this process requires some delicacy not to tear away the sand, which accident must be carefully repaired, sometimes by replacing the loose pieces, at other times with a little new sand picked out of any unused part of the mould.

Should the flask only contain one or two objects, the ingate or runner is now scooped out of the sand, so as to lead from the object to the pouring-hole; and when several objects are contained, a large central channel, and lesser passages sidewise, are made as before mentioned. The entrance round about the pouring-hole is smoothed and compressed with the thumb, that it may not break down when the metal is poured; and all the loose sand is carefully blown out of the mould, both parts of which may be placed edgewise for the more convenient application of the bellows, if necessary.

The succeeding processes are to dust the faces of both halves of the mould with meal-dust or waste flour, as explained with regard to the brickdust, and to replace the mould and boards: the whole of them are then carried to the spill-trough, upon the edge of which they are rested whilst the one board is placed exactly level with the end of the flask; but the board on the side from which the crucible will be poured, is placed about two inches below, as in Fig. 807, and the hand-screws are fixed on as shown. The mould is now held mouth downwards, that any sand loosened in the screwing down may be allowed to fall out, and the flask, according to its size, is supported either on the ground or on the surface of the trough by aid of a little bar resting against the clamp: it is now quite ready to be filled, the particulars of which process will be described when the remarks on moulding are concluded.

In works that require the first side, or 3, 4, to be cut away for imbedding the models, it is usual when the second part, or 2, 3, has been made, to destroy the first or *false* side, (which is only hastily made,) and to repeat it in a more careful manner by inverting the lower flask upon 2, 3, proceeding in all other respects as before, by which means a much more accurate and sound mould is produced.

When many copies of the same patterns are required, an *odd side* is prepared; that is, a flask is chosen to which there are two bottom sides, 4, 5. One of these latter is very carefully arranged with all the patterns, but which are only imbedded *barely half way*, so that when 2, 3 is filled, and both are turned over, the whole of the patterns are left in the new side; a second side, 4, 5, is moulded to serve for receiving the metal, as the mould is destroyed every time the metal is poured in. By this plan the trouble of rearranging the patterns for every separate mould is saved, as they are merely replaced in the odd side, and the routine of forming the two working sides is repeated.

Moulding Cored Works.—If the objects to be cast require to be so moulded that when they leave the sand they may contain one or several holes, they are said to be cored, and in such cases, a variety of methods are practised for introducing internal moulds or cores, which shall intercept the flow of the metal, and prevent it from forming one solid mass at those respective parts. For example, the pins inserted in the pewterers' moulds, Figs. 795 and 798, for producing the holes in the joints, are essentially cores. Various other methods are pursued, the three most usual of which are represented in Figs. 809, 810, and 811; the upper figures show the exact sections of the three models or casting patterns; the lower figure represents the two halves of the mould, which are respectively shaded with perpendicular and horizontal lines, the cores are shaded obliquely; and the white open spaces show the hollows to be occupied by the metal when it is poured in.

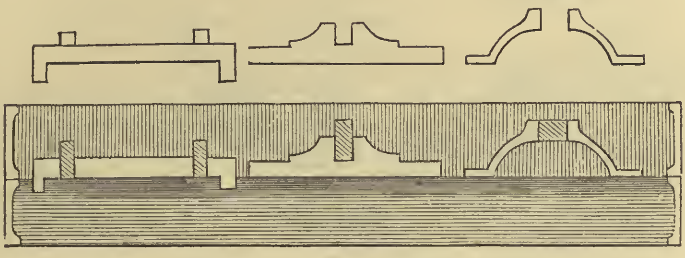
First. Many works are said to deliver their own cores; of such kind is Fig. 809, in which the cavity extends through the model, and exactly represents that which is required in the casting; the hole is either made quite parallel, or a little larger one side than the other, and gradually taper between the two. In some cases, when the hole is sufficiently taper, it delivers its own core as a continuation of the general mass of sand filling the one side of the flask; but in many or most cases, the space in the model is rammed full of strong sand at first, and it is then moulded as if to produce a plain solid casting. Before the mould is finally closed for pouring, the sand core is pushed carefully out of the pattern, and

* A steel wire, pointed and hardened, is convenient as a *picker-out;* and when fixed in the pattern and struck sidewise it serves as a *loosening bar* likewise.

inserted in the mould; to denote its precise position, one side of the core is scored with one or two deep marks in the first instance, which cause similar ridges or guides in the mould.

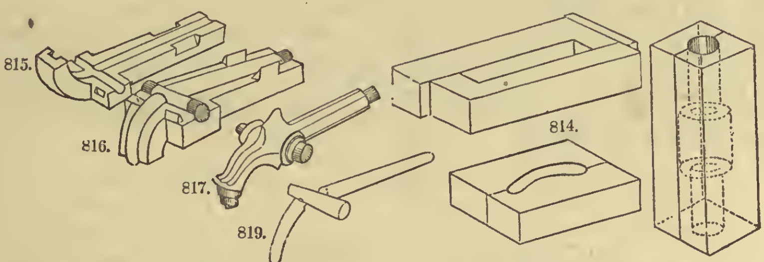
Secondly. When the hole extends only part way through, the hole of the pattern, Fig. 810, is fitted with a solid plug, sawn and filed out of soft unburnt brick, principally sand, (or the common Flanders brick;) the core is made long enough to project about as much as its own diameter, and the work is moulded as if to be cast with a solid pin, instead of a hole. The last step is to extract the filed core, and to insert it into the hollow formed by itself in the flask.

811. 810. 809.



Thirdly. The patterns for iron-work and some others are mostly made with *prints* instead of holes, as in Fig. 811; that is, the pattern-maker places square or round pieces on one or both sides of the pattern, where the square or round holes are respectively required; and the founder has moulds for forming cores of corresponding diameters or sections, and in lengths of about two to twelve inches, short pieces of which are cut off as may be required.

For example, some core-boxes are made like Fig. 812, for cylindrical cores; these divide through the axis, and are kept in position by pins; at the time when they are rammed they are fixed together by wood or iron staples, embracing three sides of the mould, or else by screw-clamps. For straight cores, say one inch wide, twelve inches long, and half-inch thick, the pieces of wood, Fig. 813, are also one inch thick, with an opening between them of twelve inches long and half-inch wide. This core-box is laid on a flat board; it is also held together with clamps, but without pins in the core-box, as the projection at the one end gives the position; it is rammed flush with both sides, and the two parts can be then separated obliquely. If it is preferred to make the cores to the precise lengths instead of cutting them off, this core-box admits of contraction in length, in the manner of the type-mould, Fig. 804; and by placing thin slips between the two halves it may be temporarily increased in width, but not in thickness. Fig. 814 is a similar core-box for a casting with circular mortises; this requires either pins or projections at each end, as it cannot be opened obliquely. Core-boxes are sometimes made of plaster of Paris; wood is much better, and metal the best of all.



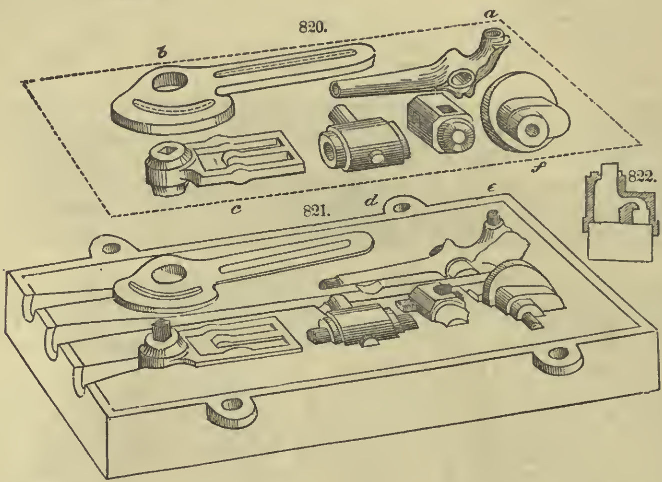
Many works require core-boxes to be made expressly for them; thus the dotted line in Fig. 812 shows an enlargement in the centre for coring a hole of that particular section. Figs. 815 and 816 represent the two halves of a brass or lead core-box suitable to the stop-cock, Fig. 817; and Fig. 819 shows the core itself after its removal from the part 816, in which it is also figured. In 817, the model from which the object is moulded, the shaded parts represent the projections, or *core-prints*, which *imprint* within the mould the places where the extremities of the core, Fig. 819, are supported when placed therein.

The various kinds of core-boxes are rammed full of new sand, sometimes with extra loam; the long cores are strengthened by wires; they are carefully removed from the boxes, and thoroughly dried before use, in the oven prepared for the purpose.*

Fig. 820 represents several examples of coring: in this view the works are represented of their ultimate forms, that is, with the holes in them; in Fig. 821, the models are arranged in the flask, with the runners all prepared, the prints of the cores being in every case shaded for distinction. Thus *a* is the

* Others prefer sand, horse-dung, and a very little loam, for making cores; these are dried, and then well burned, for which purpose they are put into an empty crucible within the fire, the last thing at night, and allowed to remain until the morning. This consumes the small particles of straw, and renders them more porous, in consequence of which the works become sounder from the free escape of air, the necessity of which was adverted to in the earlier part of this subject, and cannot be too much insisted upon.

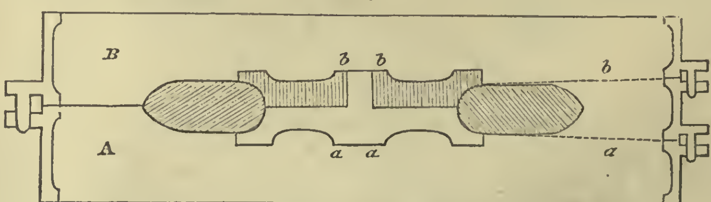
stop-cock, of which explanation has been already given; *b* has a straight and a circular mortise; this pattern *delivers its own core*, in the manner referred to in Fig. 809, as the model is made with mortises like the finished work: *c* only requires a perpendicular square core; *d* a round core parallel with the face of the flask, and in this manner all tubes and sockets are cast, whether of uniform or irregular bore, see Fig. 812; *e* has two rectangular cores crossing each other at right angles; and *f* is the cap of a double-acting pump, the core for which is shown in section by the white part of Fig. 822, the shaded portions being the metal; the great aperture leads to the piston, the two smaller are for valves opening inwards and outwards; this of course requires a metal core-box capable of division in two parts, and made exactly to the particular form.



In addition to the cores used for making holes and mortises, much ingenious contrivance is displayed in the cores employed for other works of every-day occurrence, the undercut parts of which would retain them in the sand but for the employment of these and analogous contrivances. It will now be readily understood that if, in the Fig. 790, the parts shaded obliquely were separate, there would be no difficulty in removing first the upper half of the flask, then the false cores, after which the patterns would be quite free.* By such a method, however, the circular edge of a sheave would require at least three such pieces; but Fig. 823 shows a different way of accomplishing the same thing, when the pattern is made in two parts in the manner represented.

The entire model is first knocked into the side A, the sand is cut away to the inner margin of the pattern which terminates upon the dotted line *a*, and the side A of the mould is then well dusted; a layer of sand is now thrown on, and rammed tolerably firm to form an annular core, which is made exactly level with the inner margin *b* of the pattern, and the core is well dusted; lastly, the side B is put on and rammed as usual. To extract the model, the side B is first lifted, the half pattern *b*, *b*, (which is shaded,) is removed, and the ingate is cut in the side B, to the edge of the pulley; the mould is well dusted with flour and replaced.

823.



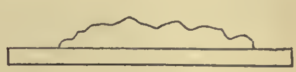
The entire mould is now turned over; A is first removed, then the remaining half pattern *a*, *a*, which must be touched very tenderly or it will break down the core; and the runner (which divides in two branches around the core) is also scooped out in the side A, which is dusted with flour and replaced, ready for pouring. Common patterns not requiring cores, are frequently divided into two parts in the above manner, so that when the mould is opened the pattern may divide and remain half in each side; this lessens the risk of breaking down the mould and the attendant trouble of afterwards repairing it.

Reversing and Figure Casting.—Supposing that an ornament, represented in section in Fig. 824, has been modelled in relief, either in clay or wax upon a flat board, from which a thin casting in brass is wanted without the tablet, the process is called reversing, and is to be accomplished in any of three ways.

* The term *false-core* is employed by the brass-founder to express the same thing as the *drawback* of the iron-founder The former calls every loose piece of the mould not intended for holes, a false-core.

First, an empty flask is placed upon the board, 824, and rammed full of sand; it assumes the appearance of 825; the second part of the flask is attached to 825, and filled to make the part 826, which is called the *back-mould;* some clay is then rolled out to the intended thickness of the casting, with a cylindrical roller running on two slips of wood or on two wires, and a narrow band of this clay is placed on 826, around the figure, that it may separate 825 and 826, exactly to the required distance, ready for receiving the metal.

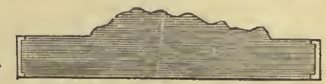
824.



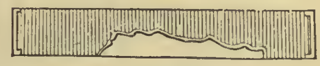
By the second mode, 825 is first made, then 826, and from the latter 827 is moulded, which is a counterpart of 825. A thin sheet of clay is then pressed all over 827, into every cavity, and cut off flush with the plane surface of the mould, by which it assumes the appearance denoted by the double line in 827. After this 826 is destroyed, and made over again in 827, but so much smaller than before as the thickness of the clay *lining;* when the new back-mould 826 is placed in contact with 825, it leaves the required space for the intended casting. This mode is only preferable to the first, when many parts of the work are nearly perpendicular; in which case, if the first mode be adopted, a portion of the back-mould 825, must be pared away at the perpendicular parts, and if incautiously performed there will be a risk of irregularity of thickness, or even of holes in the casting.

825.

826.



827.



The third mode, is to take a casting of 824 in plaster of Paris; when this is thoroughly dry it is oiled, and poured full of a cement of wax, grease, and red ochre, which is poured out again when partially set, leaving a thin crust behind, (as in the pewter handle.) A second, a third, or more layers of wax are thus added until the whole is sufficiently thick, when the wax shell is extracted, and then moulded from in the ordinary manner; the first brass casting is finished and chased to serve as the permanent pattern. The management of the wax requires practice.

In constructing such moulds additional care is given to every part of the work; for example, the sand is sifted much finer, the parting is made with fine charcoal dust, and the facing with charcoal and rottenstone mixed together in about equal parts, the mixture being of a slaty color; sometimes the loamstone, which is found in the pits where clay for making tiles is dug, is used instead of rottenstone. The moulds are well dried in an oven, or over the mouth of the furnace, and the faces are afterwards smoked over a dull fire of cork shavings; this deposites a very fine layer of soot over the face of the mould, which greatly assists the running of the metal; when this additional care is taken the works are known as *fine-castings.*

In casting figures, such as busts, animals, and ornaments consisting of branches and foliage, considerably more skill is required: the originals are generally solid, but the moulds necessarily divide into very many parts. Most persons will have had the opportunity of judging of the complexity of these moulds, from similar works in plaster of Paris, which are frequently purchased by artists and the virtuosi before the seams of the mould are removed.

A glance at these plaster-casts, at the complex and undercut form of many of these ornamental works, and at the explanatory diagram, Fig. 788, will convey some notion of the method to be pursued as well as of the trouble attending them. It is shown, for example, by the diagram just referred to, that all figured works approaching to the circular or elliptical section, require that the mould should be divided into at least three parts, except under most favorable circumstances. In the human figure and quadrupeds, the four limbs and the trunk require at least three parts each, and often many more; it will be easily conceived, therefore, that such moulded works require considerable skill and patience.

Piece after piece of the mould is successively produced, just as in making the core, Fig. 823, every piece embracing only so much of the figure, as in no part to require any core to overhang the line in which it is withdrawn. The side of the mould in which the figure is partly imbedded is first dusted with charcoal, and then the first core is very carefully rammed into the nook, and pared down to the new line of division; the green or wet sand-core is then dusted, and the second core is made, and afterwards dusted, when the moulder proceeds with the third core, and so on; every one being carefully adapted to its neighbor and withdrawn, to see that all is right, before the succeeding core is proceeded with. The relative positions of the cores amongst themselves are readily recognised and maintained by the irregularity of their forms, as in a child's dissected map, or by making a notch or two here and there, which are faithfully copied in the succeeding piece. It is frequently necessary to thrust two or more broken needles through the green cores into the neighboring parts to connect them together, in imitation of the pins in the flasks.

All the parts of the mould are dried in the oven, and the facings are smoked over a cork fire as before explained; the perfection of the casting is augmented by pouring whilst the mould is still slightly *warm,* as otherwise on cooling it has an increased affinity for damp; but the mould when *hot* is more or less filled with aqueous vapor, which is equally prejudicial.

When a figure, such as a bust, is required to be cast hollow from a solid model, it is first moulded exactly as above. The core is now produced as follows: At the foot of the bust a large space, nearly equal in length and bulk to the bust, is cut away in the sand, to serve for fixing the core in the mould, or for the *balance,* as it is called, as the core cannot be propped up at both ends. The entire hollow, that is, for the bust and the balance, is filled with a composition of about one part of plaster of Paris and two of sand or fine brickdust, mixed with a little water and poured in fluid, a few wires being placed amidst the same for additional support.

The mould is now taken to pieces to extract the core, which is then dried, thoroughly burned, and allowed to cool slowly, (which the founder calls *annealing,* from a similar method being employed in

annealing or softening the metals and glass:) the core is then returned to the mould, to see that it has not become distorted. If needful, the fitting around the balance is made good to suit the reduced magnitude of the core, which latter is then so far pared away as to leave room for the thickness of metal; this is frequently regulated by boring holes at many parts of the core with a stop-drill, having a collar to prevent its penetrating beyond the determined depth; the surface of the core is now pared down to the bottoms of the holes, as uniformly as possible. When the mould has been faced, dried, and smoked, the whole is put together for pouring, for which purpose the figure is inverted and filled from the pedestal.

Equestrian and other figures are sometimes cast in two, three, or more pieces, and joined together by solder, screws, or wires; but in all such works the aim of the founder is to leave little or nothing for the finisher or chaser to do.

Some objects which are either exceedingly complex in their form, or soft and flexible in their substance, and which do not therefore admit of being moulded in sand, in the ordinary manner of figure-casting, may be moulded for *a single copy*, provided the originals consist of substances which may be either readily melted or burned into ashes.

A cavity is made in the sand of the moulding-trough, a little larger and longer than the object, or else a wooden box of appropriate size is procured, in the midst of which the wax model may be placed; to the end of the model is added a piece to represent the runner, which will be required for introducing the metal. The composition of one-third plaster of Paris and two-thirds brickdust, mixed with water, the same as for the core of the bust, is then poured in, entirely to surround the model. The mould is first slowly dried; it is then inverted and made warm to allow the wax to run out, after which it is annealed, or burned to redness; and lastly, when cooled, it is buried in sand and filled with metal. The method necessarily throws the chance of success upon a single trial, as the model is destroyed.

Should the face of the casting be required to be particularly smooth, a small quantity of brickdust is washed, (in the manner practised with emery, and to be explained,) and mixed with very fine plaster; a coat of this is brushed over the model, which excludes air-bubbles, the model is quickly placed in its cavity, and the coarser mixture is poured in as before.

The above method exactly corroborates a mode long since described as being suitable to casting copies of small animals or insects, parts of vegetables, and similar objects; these are to be fixed in the centre of a small box, by means of a few threads attached to any convenient parts, one or two wires being added to make air-holes and ingates for the metal. A small quantity of river silt or mud, which had been carefully washed, was first thrown in and spread around the object by swinging the box about; and when partly dry, successive but coarser coats were thrown in, so as ultimately to fill up the box. When it had become thoroughly dry, the wires were first removed from the earthy mould; it was then burned to reduce the object to ashes, and when every particle of the model had been blown out, it was ready to be filled with metal.

Filling the moulds.—Having traced the formation of various kinds of moulds for brass work, we must now return to the furnace to see if the metal is in condition to be poured, which is indicated by the slight wasting of the zinc from its surface with a lambent flame. When this condition is observed, the large cokes are first removed from the mouth of the pot, and a long pair of crucible tongs are thrust down beside the same to embrace it securely, after which a coupler is dropped upon the handles of the tongs; the pot is now lifted out with both hands and carried to the skimming-place, where the loose dross is skimmed off with an iron rod, and the pot is rested upon the spill-trough, against or upon which the flasks are arranged.

The temperature at which the metal is poured must be proportioned to the magnitude of the works; thus large, straggling, and thin castings, require the metal to be very hot, otherwise it will be chilled from coming in contact with the extended surface of sand before having entirely filled the mould: thick massive castings if filled with such hot metal would be *sand-burned*, as the long continuance of the heat would destroy the face of the mould before the metal would be solidified.

The line of policy seems therefore to be, to pour the metals at that period when they shall be sufficiently fluid to fill the moulds perfectly and produce distinct and sharp impressions, but that the metal shall become externally congealed as soon as possible afterwards.

For slight moulds the carbonaceous facings, whether meal-dust, charcoal, or soot, are good, as these substances are bad conductors of heat, and rather aid than otherwise by their ignition; it is also proper to air these moulds for thin works, or slightly warm them before a grate containing a coke fire. But in massive works these precautions are less required, and the facing of common brickdust, which is incombustible and more binding, succeeds better.

The founder therefore fills the moulds having the slightest works first, and gradually proceeds to the heaviest; if needful, he will wait a little to cool the metal, or will effect the same purpose by stirring it with one of the ridges or waste runners, which thereby becomes partially melted. He judges of the temperature of the melted brass principally by the eye, as when out of the furnace and very hot, the surface emits a brilliant bluish white flame, and gives off clouds of the white oxide of zinc, a considerable portion of which floats in the air like snow; the light decreases with the temperature, and but little zinc is then fumed away.

Gun-metal and pot-metal, do not flare away in the manner of brass, the tin and lead being far less volatile than zinc; neither should they be poured so hot or fluid as yellow brass, or they will become sand-burned in a greater degree, or rather the tin and lead will strike to the surface. Gun-metal and the much-used alloys of copper, tin, and zinc, are sometimes mixed at the time of pouring; the alloy of lead and copper is never so treated, but always contains old metal;* and copper is seldom

* When the founder is in doubt as to the quality of the metal, from its containing old metal of unknown character, or that he desires to be very exact, he will either pour a sample from the pot into an ingot mould, or extract a little with a long rod terminating in a spoon heated to redness. The lump is cooled and tried with the file, saw, hammer, or drill, to learn its quality.

cast alone, but a trifling portion of zinc is added to it, otherwise the work becomes nearly full of little air-bubbles throughout its surface.*

Some persons judge of the heat proper for pouring, by applying the skimmer to the surface of the metal, which when very hot has a motion like that of boiling water; this dies away and becomes more languid as the metal cools. Many works are spoiled from being poured too hot, and the management of the heat is much more difficult when the quantity of metal is small.

The mixture and temperature of the metal being found to be proper, it is poured in the manner represented in Fig. 788; the tongs are gradually lowered from the shoulder down the left arm, and the right hand is employed in keeping back the dross from the lip of the melting-pot. A crucible containing the general quantity of 40 or 50 lbs. of metal, can be very conveniently managed by one individual; but for larger quantities, sometimes amounting to one hundred weight, an assistant aids in supporting the crucible, by catching hold of the shoulder of the tongs with a *grunter*, an iron rod bent like a hook.

Whilst the mould is being filled, there is a rushing or hissing sound from the flow of the metal and the escape of the air; the effect is less violent when there are two or more passages, as in heavy pieces, and then the jet can be kept entirely full, which is desirable. Immediately after the mould is filled, there are generally small but harmless explosions of the gases, which escape through the seams of the mould; they ignite from the runners, and burn quietly; but when the metal *blows*, from the after-escape of any confined air, it makes a gurgling, bubbling noise, like the boiling of water, but much louder, and it will sometimes throw the fluid metal out of the runner in three or four separate spirts. This effect, which mostly spoils the castings, is much the most likely to occur with cored works, and with such as are rammed injudiciously hard, without being, like the moulds for fine castings, subsequently well dried.

The moulds are generally opened before the castings are cold, and the founder's duty is ended when he has sawn off the ingates or ridges, and filed away the ragged edges where the metal has entered the seams of the mould; small works are additionally cleaned in a *rumble*, or revolving cask, where they soon scrub each other clean.

Nearly all *small* brass works are poured *vertically*, and the runners must be proportioned to the size of the castings, that they may serve to fill the mould quickly, and supply at the top a mass of still fluid metal, to serve as a *head* or pressure for compressing that which is beneath, to increase the density and soundness of the casting. Most *large* works in brass, and the greater part of those in iron, are moulded and poured *horizontally*, and the process being exactly alike for both metals, we must refer the reader to the following.

Iron-Founders' Flasks, and Sand-moulds.—The process of moulding works in sand is essentially the same both for brass and iron castings; but the very great magnitude of many of the latter give rise to several differences in the methods: it will suffice, however, to advert to the more important points in which the two practices differ, or to those which have not been already noticed; I shall therefore commence with a few remarks upon the flasks and the sand.

In the greater number of cases, the iron-founder moulds and casts his works horizontally, with the flasks lying upon the ground; frequently the top part only is lifted; and in the largest works the lower part of the flask is altogether omitted, such pieces being moulded in the sand constituting the floor of the foundry; in these cases the position of the upper flask is denoted by driving a few iron stakes into the earth, in contact with the internal angles of the *lugs*, or projecting ears of the flasks.

The sand would drop out of such large flasks, if only supported around the margin; they are consequently made with cross-bars, or wooden *stays*, a few inches asunder, which, unless the entire flask is made of wood, are fixed by little fillets cast in the solid with the sides of the iron flasks. A great number of hooks in the form of the letter S, but less crooked at the ends, are driven into the bars, and both the bars and hooks are wetted with thick clay-water, so that the sand becomes entangled amidst them, and is sustained when the flask is lifted. Some flasks require the force of either two or several men, who raise them up by iron pins or handles projecting from the sides of the flask; they are then placed upon one edge, and allowed to rest against any convenient support whilst they are repaired, or they are sustained by a prop.

The very heavy flasks are lifted with the crane, by means of a transverse beam and two long hangers, called *clutches*, which take hold of two gudgeons in the centres of the ends of the flask; it can be then turned round in the slings, just the same as a dressing-glass, to enable it to be repaired.

The modern iron-founders' flasks are entirely of iron, and do not require the wooden stays, as they are made full of cross-ribs nearly as deep as the flask itself, and which divide its entire surface into compartments four or five inches wide, and one to two feet long. On the sides of every compartment are little fillets, sloping opposite ways, so as to lock in the small bodies of sand very effectually. When these top flasks are placed upon middle flasks without ribs, as in moulding thick objects, the two parts are *cottered* or keyed together, by transverse wedges fixed in the steady pins of the flask; lifters or *gaggers* are then placed amidst the sand; these are light T-shaped pieces of iron, wetted and placed head downwards, the tails of which are largest at top, so as to hold themselves in the sand, the same as the keystone of an arch is supported. The gaggers are placed at various parts to combine the sand in the two flasks, and they fulfil the same end as the iron hooks and nails driven into the wooden stays of the old-fashioned flasks.

The bottom flask, or drag, has sometimes plain flat cross-ribs, two inches wide, (like a flat bottom with square holes,) that it may be turned over without a bottom-board; and unless the flasks have swivels for the crane, they have two cast-iron pins at each end, and one or more large wrought-iron handles at each side, by which they may be lifted and turned over by a proportionate number of men.

* The engraved cylinders for calico-printing are required to be of pure copper, and their unsoundness when cast in the usual way was found to be so serious an evil, that it gave rise, in 1819, to Holingrake's patent for casting the metals under pressure.

The sand of the iron-founder is coarser and less adhesive than that used by the brass-founder The parting-sand is the burned sand which is scraped off the castings; it loses its sharp, crystalline character from being exposed to the red heat. The facing-sand is sometimes only about equal parts of coal-dust and charcoal-dust, ground very fine; at other times, either old or new sand is added, and for large, thick works a little road-drift is introduced. All these substances get largely mixed with the sand of the floor, and lessen its binding quality, which is compensated for by occasional additions of new sand, and by using more moisture with the sand, as before extracting the patterns, the iron-founder wets the edges of the sand with a sponge, which has sometimes a nail tied to it to direct the water in a fine stream; for heavy works a watering-pot is used.

The *green-sand moulds* are made as in the brass-foundry, of the ordinary stock of old moist sand; these are often filled as soon as they have been made.

The *dry-sand moulds* are made in the same manner, but with new sand containing its full proportion of loam; these moulds are thoroughly dried in a large oven or stove, and then blackwashed or painted, with thin clay-water containing finely-ground charcoal; this facing is also thoroughly dried before the moulds are poured.

The *loam-moulds*, which are much used for iron-castings, and somewhat also for those of brass, are made of wet loam with a little sand, ground together in a mill to the consistence of mortar; the moulds are made partly after the manner of the bricklayer and plasterer, as will be explained; the loam moulds also are thoroughly dried, blackwashed, and again dried, as from their greater compactness they allow less efficient escape for the vapor or air, and therefore they must be put into the condition not to generate much vapor when they are filled.

Iron moulds are also employed for a small proportional number of works which are then called *chilled castings;* and occasionally the methods of sand-casting and chilling are combined, as in some axletree-boxes, which are moulded from wooden patterns in sand, and are cast upon an iron core. To form the annular recess for oil, a ring of sand, made in an appropriate core-box, is slipped upon the iron mandrel, and is left behind when the latter is driven out of the casting.

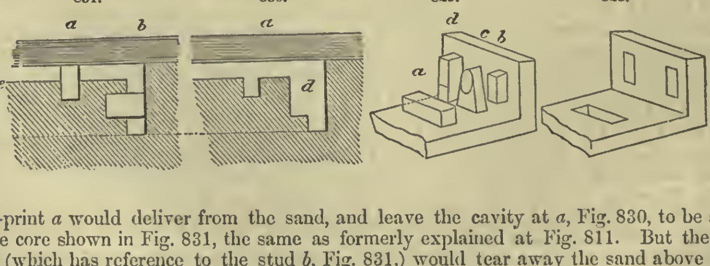
It would be a useless repetition to enter into the details of moulding ordinary iron-works; but from the horizontal position of the flasks, it is necessary that the part of the work which is required to be the soundest, and most free from defects, should be placed downwards, as the metal is more condensed at the lower part, and free from the scoria or *sullage* which sometimes renders the upper surface very rough and full of minute holes. As the flasks almost always lie on the ground, it is also found the most convenient to retain them in contact by placing heavy weights upon them; the foundry should in consequence have an abundant supply of these.

The flasks require to be poured through a hole in the upper half, as seen at *r*, Fig. 837, which hole is formed by placing a wooden *runner-stick* in the top part A, whilst it is being rammed; and a small channel is afterwards cut sidewise into the mould. Sometimes two, three, or even half-a-dozen or more runners are put to one single casting, either when it requires a great weight of metal, or when it is large but slight, as in trellis-work, in which case the metal might cool before filling the mould, if only introduced at one single runner.

When the runners are required to be lofty, either to supply pressure to the metal, or as a reserve to fill up the space left by its contraction in cooling, iron rings of six or eight inches diameter are piled up to the required height, to support the tube of sand contained within them. Small objects that are poured from one hole, are frequently moulded with two runners, that the metal may *flow* through the mould, and that there may be a sufficient supply to meet the shrinkage, and also to supply head or pressure; another advantage also results, as it assists in carrying off the scoria or *sullage*.

The iron-founder employs all the methods of coring explained at pages 246 to 248, and also others of an entirely different kind but little required in brass-works; namely, for lateral holes in the parts of the castings buried beneath the general surface of the mould, and which are explained by the Figs. 828 to 831. Thus, 828 represents the finished casting, 829 the model of the same, 830 the appearance of the bottom flask or drag when the pattern is first removed, and 831 the flask and cores when closed ready for pouring; the moulds are inverted, and the same letters of reference refer to similar parts of all these figures.

831. 830. 829. 828.



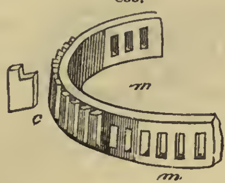
The core-print *a* would deliver from the sand, and leave the cavity at *a*, Fig. 830, to be afterwards filled by the core shown in Fig. 831, the same as formerly explained at Fig. 811. But the core-print *b*, Fig. 829, (which has reference to the stud *b*, Fig. 831,) would tear away the sand above it in withdrawing the pattern; therefore the print *b* should, like *d*, Fig. 829, extend to the face of the pattern, or the parting line, represented by *c*, Fig. 831. This being the case, the pattern would leave the space denoted at *d*, Fig. 830; the core is put down sidewise to the bottom of the recess, and extends entirely across the same; the small open space above is made good with the general surface, as shown by the shade lines in Fig. 831, and this filling in, at the same time fixes the core precisely where denoted by the print *d*, which latter has a mark to show to the moulder where the core is to end. The circular

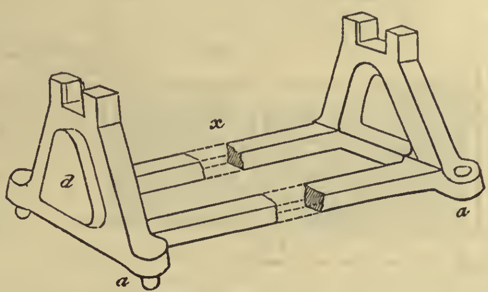
hole requires the core-print shown at *c*, Fig. 829; the cores themselves are made in the core-boxes, 812 and 813, before explained.

Fig. 832 represents the model and core-print, from which the finished casting shown at Fig. 832 might be made from a solid pattern in a two-part flask; it would be inverted, and the parting would be made

832.

833.



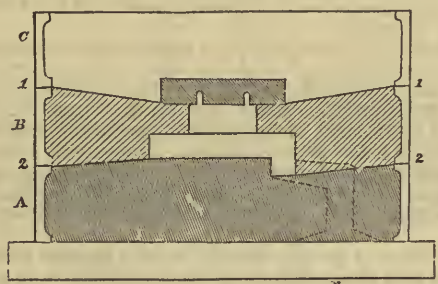


upon the line *x*. The prints for the four holes *a a*, would be placed in the top flask, and those for the great apertures or panels *d*, would be made in a core-box of the express form, and as thick as the pattern and core-print measured together. The core would be deposited edgewise into the core-print, and the upper corners of the mould will be made good, as explained in Fig. 831.

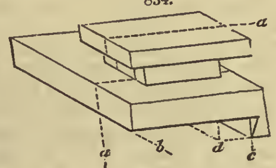
By the same method, a mortise-wheel, or one with spaces around its edge, as at *m m*, Fig. 833, to be filled with wooden cogs, might be made with a series of core-prints, as at *c*, brought up flush with the parting of the mould; if every print were filled with a core such as Fig. 833, made in an appropriate core-box, the matter would be accomplished with great facility and truth.

The iron-founder makes frequent use of flasks which divide in three or four parts; this is done in many cases simply to increase the depth of the contained space; in which case, when wooden flasks were employed, they admitted of being temporarily fixed together by dogs, or large iron staples, driven a little way into the neighboring flasks, but the modern iron flasks are fixed by cotters. The following examples will show the nature of some other uses to which the flasks with several partings are applied.

835.



834.



A casting, such as Fig. 834, which represents the top of a sliding-rest for a lathe, might be moulded in a very deep two-part flask, if the parting were made upon the dotted line *a a;* but there would be very great risk of tearing down the mould in drawing out the pattern; and from the depth, there would be scarcely a possibility of repairing it, and the metal would probably be strained. It would be also possible to mould it with the joining upon the line *b*, provided several cores were employed; but the mode adopted is more convenient than either of these, when the pattern is made in two parts, and the flask in three, as in Fig. 835.

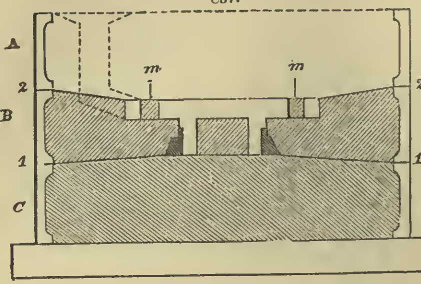
A and B are first united and partly filled with sand, the pattern is knocked in as represented, and the whole well rammed, especially in the groove, the parting being made on the line 1 1, and dusted. C is now put on, filled, and struck off level; a board is put above it, and A B C are all turned over together, A becoming the top.

A is now removed, and the sand is cut away to make the second parting on the line 2 2, after which A is replaced, and the runner-stick is inserted to make the runner *r*. On removing the pattern, the runner-stick *r* is first taken out, A, or the top part of the flask, is lifted off, and the white part of the pattern is drawn out; B, or the middle part, is then lifted, and the last or shaded piece of the pattern is drawn out of the mould, which is now put together again, and poured through *r;* so that the top-surface of the pattern, as seen in both views, becomes the *face,* from being cast downwards, or upon the lowest piece C, of the flask, called the drag.

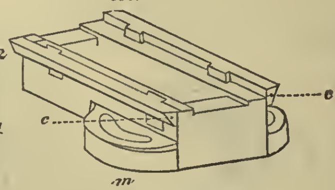
The part *c*, Fig. 834, might be cast with a chamfer in three different ways; although, in small castings, it is more usual to cast it square and plane it out of the solid. First, the pattern might be moulded square, and the top A, after removal, might be worked to the angle by aid of the trowel and a chamfered slip of wood, used as a gage; or secondly, by the employment of a core, the print of which is represented by the dotted lines terminating at the angle *d*, Fig. 834; or thirdly, by having a loose slip on the pattern sliding on the line *c*, Fig. 834, so as to be drawn off when the top A had been lifted

This last method is analogous to that represented in Fig. 836, also intended for a sliding-rest, and which might be cast in a two-part flask, if the two chamfers *c c* were fitted loosely upon slides, as shown; but a three-part flask is more convenient, as explained by Fig. 837, in which the pattern is inverted

837.



836.



The lowest piece C, or the drag, is parted upon the line 1 1, but its sand extends upwards between the two sides of the pattern, as shown by the shade lines. The middle piece B is parted through the line 2 2; and lastly A, the top, is filled up level, the runner-stick at *r* being inserted at the time; A is first lifted, and all the pattern is then removed, excepting the chamfered bars and their slides, which are represented black; this pattern delivers its own cores for the circular mortises *m m*, the sand forming them being a part of that in B, or the middle flask; lastly, B is lifted, and the chamfer-slips are picked off from C. This pattern may consequently be moulded without turning over the flask, and every part of the mould is quite accessible for repair.

The pedestal of the swage-block, is another good example of moulding in a three-part flask. The model is made with the upper fillet loose, also with the sides solid, or without the holes, and the object is moulded as it stands. The top part of the flask opens at the upper moulding, and which latter is then removed from the pattern; the middle flask divides at the plinth or flange, so that when this has been lifted, the pattern also may be withdrawn, leaving a square pedestal of sand, as large as the interior of the model, standing upon the bottom part or drag, as in Fig. 837. The panels are made by means of a core-box, of the kind Fig. 814: the box is exactly as thick as the metal to be cast; and the circular cores are then fixed upon the pedestal of sand by means of a few wires or nails, after which the flask is put together, ready for pouring.

If the casting here referred to, had four fluted columns at the four angles, either with a large cap to each, or with a square entablature connecting the whole of them, the object might be also cast in one piece, if moulded in a three-part flask. After removing the top flask, the entablature and capitals would be first withdrawn, the columns being divided through their *smallest* diameters; the mould would be then turned over, and upon lifting off the drag, or bottom piece, the remainder of the pattern could be drawn, either in one single piece, or if the pillars were loose, the five parts could be more safely extracted; the three-part mould would be put together again, and reversed for pouring. In this general manner, by making either the mould or the pattern, or both, in different pieces, and by the judicious employment of cores and drawbacks, objects apparently the most untractable are cast with very great perfection.

The iron-founders are likewise very dexterous in making castings in some respects different from the patterns from which they are moulded: thus, if the pattern be too long, or that it be temporarily desired to obliterate some few parts, the mould is made of the full size and *stopped-off*, additional sand being worked into the mould, by aid of the trowel and some temporary piece of wood, to represent the imagined termination of the pattern. On the other hand, any simple enlargement or addition is not always added to the pattern, but it is frequently *cut out* of the mould with the trowel, in a similar manner.

Many common works, such as plates, gratings, parts of ordinary stoves, and simple objects, are made to *written* measures, and without patterns, as a few parallel slips of wood to represent the margin of the casting are arranged for the purpose upon a flat body of sand, which is modelled up almost entirely by hand; but for all accurate purposes and for machinery, good and well-made patterns are indispensable, and to some particulars of which a little attention will be now devoted.

Remarks on Patterns for Iron Castings.—The construction of patterns for iron castings requires not only the observance of all the particulars conveyed, but in addition, the large size of the models, the peculiar methods employed in moulding them, and the nearly inflexible nature of the iron castings when produced, call for some other and important considerations; and which should not be entirely overlooked, even in works of comparatively small size, or it may lead to failure and disappointment.

Thus, it becomes necessary to make patterns in some degree larger than the intended iron castings, to allow for their contraction in cooling, which equals from about the ninety-fifth to the ninety-eighth part of their length, or nearly one per cent. This allowance is very easily and correctly managed by the employment of a *contraction-rule*, which is made like a surveyor's rod, but one-eighth of an inch longer in every foot than ordinary standard measure. By the employment of such contraction-rules, every measurement of the pattern is made proportionally larger without any trouble of calculation.

When a wood pattern is made, from which an iron pattern is to be cast, the latter being intended to serve as the permanent foundry pattern, as there are two shrinkages to allow for, a *double* contraction-rule is employed, or one the length of which is one quarter of an inch in excess in every foot. These rules are particularly important in setting out alterations in, or additions to, existing machinery; the

latter is measured with the common rule, and the new patterns are set out, to the same nominal measures, with a single or double contraction-rule as the case may be, the three being made in some respects dissimilar to avoid confusion in their use; the entire neglect of contraction-rules incurs additional trouble and uncertainty.*

Patterns for iron castings are much more frequently divided into several parts than those for brass; for instance, the division into two equal parts, after the manner of Fig. 823, (but without reference to the under-cutting,) is very common, as both the pattern and flask separate when the top part is lifted, and the halves of the pattern can then be drawn out from the halves of the flask with much less risk of tearing down the sand.

Fig. 790, if small, would be moulded as represented, with false cores or drawbacks; but if it were a large fluted column, the iron-founder would employ a solid two-part flask; the shaded parts would together represent the body of sand in the drag, and the pattern would be made in *three* parts, something like a boot-tree. When the top flask had been lifted, the central slice of the pattern, extending from the two upper to the two lower angles, would be withdrawn vertically, and the two outer pieces would be released sidewise. The general rule is to divide the circumference of the pattern into six equal parts, and to let the central slice equal one of them in width.

The figures 835 and 837, representing two parts of a slide-rest, and the pedestal, are some amongst many of the common examples of the division of the patterns; and with which may be associated the numerous subdivisions of the mould instead of the pattern, by the employment of cores, many applications of which have been also explained. All these matters display much interesting and ingenious contrivance, resorted to either to render possible the operation of moulding, or to facilitate its performance.

To lessen the distortion of castings from their unequal contraction in cooling, it is important that the models should be nearly symmetrical. For example, bars or rods of all the sections in Fig. 789 may be expected to remain straight; perhaps *g* is the most uncertain, but if the lower fins of *e* and *h* were removed, their flat surfaces then exposed to the sand would become rounding or convex in length, from the contraction of the upper rib being unopposed by that of a similar piece on the under side. Bars and beams, the sections of which resemble the letter **I**, are of the most favorable kind for general permanence, and also for strength, and large panels may be cut out from their central plates to diminish their weight without materially reducing their stability. They are much used, not only in building, but also in the framing of machinery, which is in a great measure based upon the same general rules.

It is also of great importance, especially in castings of large size, that the *thickness* of the metal should be nearly alike throughout, so that it may cool at all parts in about the same time. Should it happen that one part is set or rigid, whilst another is semi-fluid, or in the act of crystallizing, there is great risk of the one part being altogether torn from the other and producing fracture. Or should the disturbing force be insufficient to break the casting, it may strain the metal nearly to its limit of tenacity or elasticity; so that a force far below that which the casting should properly bear may break it in pieces.

An example of this is seen in wheels with very light arms and heavy rims or bosses. The arms sometimes cool so quickly as to tear themselves away from the still hot rim or nave; or when the arms are solidified without fracture, the contraction of the rim may so compress the spokes endwise as to dish the wheel, (in the manner of an ordinary carriage-wheel,) and thereby strain the casting nearly or quite to the point of fracture. The arms are sometimes curved like the letter **S**, instead of being straight and radial; the contraction then increases their curvature with less risk of accident than to straight arms.† A more elegant way of avoiding the mischief was invented by Mr. Isaac Dodd, of the Horsley Iron Works, by placing the spokes as *tangents* to the central boss, in which case the contraction of the rim makes a small angular change of position in the boss; for the rim in thrusting the spokes inwards, causes the boss to twist round a little way with far less risk of fracture.‡

The destructive irregularity of thick and thin works is partly averted by uncovering the thick parts of the casting, or even cooling them still more hastily, by throwing on water from watering-pots. In wheels this has been done by a hose, the axis of which is concentric with the wheel, the arms being all the time surrounded by the sand to retard their cooling; but it is the most judicious in all patterns, to make the substance for the metal as nearly uniform throughout as circumstances will admit, so as not to require these modes of partial treatment, which often compromise the ultimate strength of the casting.

Another mode sometimes adopted for avoiding the fracture of wheels, from the great dissimilarity of their proportions, is by inserting *wrought-iron arms* in the mould, but they do not always unite kindly with the iron of the rim and the nave. The same inconvenience occurs when iron pins are inserted in the ends of either iron or brass castings, to serve for their attachment to their respective places. In iron castings it frequently produces the effect of chill casting, so as to render the works difficult to be turned or filed at the junction, and there is risk of the casting becoming blown or un-

* The contraction of brass is nearly three-sixteenths of an inch in every foot, but from the small size of brass castings the contraction-rule is less required for them, as the differences may be easily allowed for without it.

Iron castings weigh about fourteen times as much as the ordinary deal and fir patterns from which they are made, that being nearly the ratio of the specific gravities of those materials. All these matters are entered into in the pamphlet, "A New System of Scales of Equal Parts," and the paper "On a Scale of Geometrical Equivalents for Engineering and other Purposes," Lond. and Edin. Philos. Mag., July, 1838, wherein are described numerous applications of scales of equal parts to the purposes of drawing and calculation, and to the comparison and conversion of all kinds of measures, weights, and other quantities.

† It appears to be often desirable to supersede the straight diagonal braces of iron castings by curved lines, which are both more ornamental, and better disposed to yield to compression or extension by a slight alteration in their curvature.

‡ Mr. Dodd had to contend with the shrinking of the *nave*, which was the last to cool; the accidents therefore occurred from the tension, instead of the compression of the spokes; this equally fatal effect was completely remedied by placing the arms as tangents.—*Trans. Soc. of Arts*, vol. li. p. 66.

sound in either case. When the pins are heated before being placed in the mould, they become nearly cold before the metal can be poured, and they also endanger the presence of a little steam or vapor, which is detrimental; therefore they are more generally put in cold, notwithstanding the sudden check they then give to the fluid metal.

The patterns for iron castings of large size are necessarily very expensive, especially those for hollow cylinders and pans, many of which are so large that it would be impossible to find solid pieces of wood from which the patterns could be made; either with sufficient strength for present use, or with the necessary permanence or form for a subsequent period, as they would be almost sure either to break, or to become distorted from the effects of unequal shrinking. Such patterns, therefore, require to be made of a great many thin layers or rings of wood, each consisting of 6, 8, or 12 pieces, like the felloes of wheels, so that in all parts the grain may be nearly in the direction of a tangent.

As they are glued up, every succeeding layer is connected with the former, by glue and wooden pins or dowels, and the whole is afterwards turned to the tubular or hemispherical form, as the case may be. As the castings are generally required to be rather thin, such models are not only very expensive, but also very liable to accident; and besides, it frequently occurs that only one or two castings of a kind may be required, which makes the proportional cost of the patterns excessive.

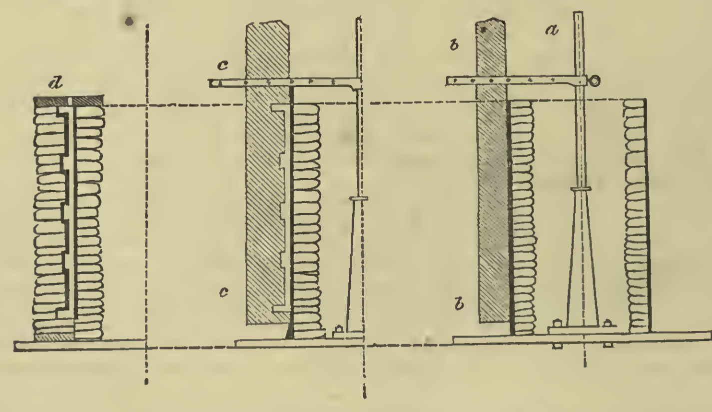
It fortunately happens, however, that this case, which is one of the most costly and uncertain by the employment of ordinary wood or metal patterns, becomes exceedingly manageable by a peculiar and simple application of the art of turning, (the one great centre of the constructive arts, to which these pages are intended immediately and collaterally to apply;) and by which process, or one branch of *loam moulding*, to be explained in the following section, patterns are not generally required.

Loam Moulding.—Figs. 838, 839, and 840, are intended to illustrate this process as regards a steam cylinder. Fig. 838 is the entire section of the mould in its first stage; Figs. 839 and 840 are the half sections of the second and third stages, preparatory to burying the mould in the pit in which it is to be filled.

The inner part of the loam-mould is called the *core* when small, but the *nowel* when large; the outer is called the *case* or the *cope*. Each part is built upon an iron loam-plate, or a ring cast rough on the face, and with four ears by which it may be lifted. The mould is occasionally erected upon four shallow pedestals of bricks for the convenience of making a fire beneath it to dry the loam; at other times it is made upon a low truck upon which it may be wheeled into the loam-stove, which is heated to about the temperature of 300 to 400 degrees Fahrenheit.

A vertical axis *a*, is mounted in any convenient manner, frequently in two holes in the truck itself, or as shown in Fig. 838, in a pedestal or socket erected upon the truck; at other times the axis is mounted in a hole in the loam-plate, and in any bearing attached either to the building, or its roof.

840. 839. 838.



The first step is to fix upon the spindle the templet *b b*, at the distance of the radius of the cylinder, either by one or two *clutches*, with various binding screws. An inner cylinder of brickwork is then built up, plastered by the hands with soft loam, (which is represented black in all the figures,) and scraped into the cylindrical form by the radius board, which is moved round on its axis by a boy. When the surface is smooth and fair it is thoroughly dried, after which it is brushed over with blackwash, and again dried. The charcoal-dust in the blackwash serves as a parting, to prevent the succeeding portions of the loam-mould from adhering to the first.

The templet *c c*, Fig. 839, cut exactly to the external form of the cylinder, is now attached to the axis at the distance from the core required for the thickness of the metal: some additional loam is thrown on to form the *thickness*, which is smoothed in the same careful manner as the centre, after which the templet and spindle are dismounted, and the thickness, which is represented white in Figs. 839 and 840, is also dried and blackwashed.

The ring for the outer case or cope is now laid down, and its position is denoted either by fixed studs or by marks; and the outer case represented in Fig. 840, is built up of bricks and loam, with an inner facing of loam worked very accurately to the turned thickness. The new work or the cope is also thoroughly dried, and afterwards lifted off very carefully by means of the crane and a cross-beam with four chains. This process likewise drags off the thickness, which usually breaks in the removal; its

remains are carefully picked out of the cope, both parts of the mould are repaired, and again blackwashed and dried.

When the cylinder requires *ports* at the ends, or the short tubes with flanges for attaching the steam passages, models of the tubes are worked into the cope, and are afterwards withdrawn; the cores are made in core-boxes, and are partly supported by the outer extremity, and partly upon *grains*, or two little plates of sheet-iron connected by a central wire, the whole being equal to the thickness of the metal at the part. When steam passages are wanted, either along the side, or around the cylinder they are worked up in clay upon the thickness, and duly covered in by the cope; their cores are supported, partly by their loose ends, and partly by grains, which become entirely surrounded by, and fixed in the metal, when it is poured.*

The mould is now put together in a pit sunk in the floor of the foundry, and the two iron plates are screwed together; the surrounding space being rammed hard to prevent the mould from bursting open, but the inner part is left much more loose for the escape of the air. The top edges of the mould are covered over with a *loam-cake*, (which has been previously made and dried,) or a ring three or four inches thick, strengthened with iron bars amidst the clay, the joining being made air-tight by a little cow's hair, and by the pressure of a quantity of iron weights; the loam-cake is generally perforated with many holes, as shown at *d*, for the entry of the metal and the escape of the air. But provision must always be made in casting thin cylinders, boxes, and such like forms, for the breaking up of the core as soon as the metal is set, to prevent the metal *scoring* or rending from its contraction upon a rigid, unyielding centre.†

Large pans, and various other circular works, are moulded precisely in the same way as cylinders, except that curved templets are used, and that towards the conclusion, the apertures through which the spindle passed are filled in and worked by hand to the general surface.

Water-pipes are made much in the same mode, but the cores for these are turned upon an iron tube pierced full of holes, which is laid horizontally across two iron trestles with notches, and is kept in rotation by a winch-handle at the end; there is also a shaper-board or scraper fixed parallel with the axis: this primitive apparatus is called a *founder's lathe*.

The perforated tube (serving as the mandrel) is first wound round with haybands, then covered with loam, and the core is turned, dried, and blackwashed; the thickness is now laid on and also blackwashed, after which the object is moulded in sand. The thickness is next removed from the core, which latter is inserted in the mould, and supported therein by the two prints at the extremities, and by grains with long wires, the positions of which may be seen by the little bosses on the pipe, the metal being there made purposely thicker to avoid any accidental leakage at those parts. When pipes are cast in large quantities, they are moulded from wooden patterns in halves, so that it only becomes necessary to turn the core; and this, when made in the above manner, is sufficiently porous for the escape of the air.

The moulds for crooked pipes and branches are frequently made in halves, upon a flat iron plate. An iron bar or templet of the curve required is fixed down, and a semicircular piece of wood, called a *strickle*, is used for working and smoothing the half core; next a larger strickle is used for laying on the thickness, the two halves are then fixed together by wires, and moulded from in the sand-flask; the thickness is now stripped off the core, which is fixed in the mould by its extremities, and if needful, is supported also upon grains.

By the employment of these means, although the loam-work requires time for the drying, yet with ordinary care an equality of thickness may be maintained, notwithstanding the complexity of the outline, and without the necessity for wooden patterns.

Very many of the large works in brass are also moulded in loam, the management being in most respects exactly the same as for iron, except that in some ornamental works wax is more or less employed, and is melted out of the moulds before the entry of the metal; a very slight view of the methods will serve as a sequel to the subject of brass-founding.

Large bells are turned in almost the same manner as iron cylinders or pans, by means of wooden templets, edged with metal, and shaped to the inner and outer contour of the core and thickness. The inscription and ornaments are either impressed within the cope, the clay of which is partially softened for the purpose, or the ornaments are moulded in wax, and fixed on the clay thickness before making the cope. Less generally the whole exterior face of the bell, or indeed its entire substance, is modelled in wax, and melted out before pouring. In any case, the concluding steps in filling up the apertures where the spindle passed, are to attach a dissected wooden pattern of the central stem and of the six *cannons* or ears by which the bell is slung, which parts are moulded in soft loam; and then, the parts

* There is always some uncertainty of the sound union of the grains, or other pieces of iron, with the cast-metal. Some cast them in iron and file them quite bright; others also tin them, apparently to preserve them from rust, as the tin must be instantly dissipated by the hot metal. Grains should always present clean metallic surfaces, and when used for very thin castings, to prevent them from dropping out, the wires are nicked with a file that they may be keyed in the metal. It is, however, better to avoid the use of grains, which may be generally done by giving the core *sand bearings*, and afterwards plugging up the holes in the casting.

† The largest cylinders, such as those of the Cornish pumping-engines, of 80, 90, and 95 inches bore, and 12 or 14 feet in length, and the blowing cylinders of blast furnaces, sometimes 105 inches bore, are made without the employment of the thickness. The case or cope is built up in the pit, and turned *inside*, with a radius bar, and the core is erected on a plate on the floor, and turned *outside* to a gage; when dried, it is lowered into the other by the crane. The cylinders are cast one foot or upwards longer than required, to serve as a head of metal and make the top edge sound, and thus much is cut off before they are bored.

To enable the mould to resist the great pressure of the lofty column of fluid metal, (equal at the base to near 60 pounds on every square inch,) the core is strengthened by diametrical iron bars entering slightly into the brickwork: the outer cylinder is surrounded at a small distance by iron rings piled one on the other, the interval being rammed with sand; and stays are placed in all directions from the rings to the sides of the pit, which is either lined with brickwork, or when liable to be inundated with water, it is made of iron like a water-tight caisson.

Small cylinders are moulded in sand from wooden models, and only the cores are turned in loam; for cylinders of the smallest size the cores are made of sand in core-boxes, as already explained.

having been dried and replaced, and the iron ring for the clapper inserted, the whole is ready for the pouring-pit. The heaviest bells are moulded within the pit the same as huge cylinders.

Brass guns are also moulded in loam, and in a somewhat peculiar manner; a taper rod of wood, much longer than the gun, is wound round with a peculiar kind of soft rope, upon which the loam is put for making the rough casting-model of the gun, which is turned to a templet; the work is executed over a long fire, to dry it as it proceeds, and the model is made about one-third longer than the gun itself. The model, when dried and blackwashed all over, is covered with a *shell* of loam, not less than three inches thick, secured by iron bands; the shell is also carefully dried; after this the taper bar is cautiously driven out from its small end, the coil of rope is pulled out, and so likewise is every piece of the clay model of the gun.

The parts for the cascable and trunnions, which should have been worked separately upon appropriate wooden models, are then attached to the shell. Should the gun have dolphins, or any other ornamental figures, they are modelled in wax and fixed on the clay model before the shell is formed, and are then melted out to make the required space for the metal.

When all is ready and dried, six, eight, or more of these loam cases, or shells, are sunk perpendicularly in a pit at the mouth of the reverberatory furnace, and the earth is carefully rammed around them; at the same time a vertical runner is made to every mould, to enter either at the bottom or not higher than the trunnion: the upper ends of the runners terminate in the bottom of a long trough or gutter, at the far end of which is a square hole, to receive the excess of metal.

In casting brass guns, tapping the furnace is rather a ceremony, and certainly an imposing sight: the middle and the end of the trough are each stopped by a shovel or gate held across the same; and the runners are all stopped by long iron rods, held by as many men. When all is pronounced to be *ready*, the stopper of the furnace is driven inwards with a long heavy bar swung horizontally by two or three men, and the metal quickly fills the trough; on the word of command, "*number one, draw*," the metal flows into the first mould, and fills it quickly but quietly from the bottom; the mould being open at the top, no air can be accidentally enclosed. Numbers two, three, and four are successively ordered to draw. The first shovel is then removed from the great channel, and now the guns, five to eight or ten, as the case may be, are similarly poured and filled to the level of the trough; after which the last shovel is withdrawn, and the residue of the metal is allowed to run into the square bed or pit prepared for it. The flow of metal from the furnace is regulated by the tapping-bar, the end of which is taper, and is thrust more or less into the mouth of the furnace as required; the trough and runners are thus kept exactly full, which is an important point in most cases of pouring, as it prevents a current of air being carried down along with the metal.

Large bells are poured much in the same manner, except that the runners are at the top, and the metal runs from the great channel, through smaller gutters, to every sunk mould, the stoppers for which are successively drawn. For quantities of brass intermediate between the charge of an ordinary crucible, and such as require the reverberatory furnace, the large ladles or shanks of the iron-founder are used; the contents of four or six crucibles being poured into the shank as quickly as possible, and thence in one stream into the mould.

The author of the article Founding, in the Encyclopedia Metropolitana, minutely describes three ways of casting large hollow statues, which are briefly as follows:

First; a rough model of the figure is made in clay, but somewhat smaller than its intended size; it is covered over with wax, which is modelled to the required form, or the wax is worked up in separate pieces and afterwards attached: various rods or cylinders of wax to make the apertures for the runners and air-holes, are fixed about the figure and led upwards. The whole is now surrounded with a coating of loam and similar materials, the inner portion of which is ground very fine and laid on with a brush, like paint; and the outer part is secured with iron bands. When all has been partially dried, a fire is lighted beneath the grating on which the figure is built, to cause the wax to run out through one or more apertures at the base, which are afterwards stopped, and all is thoroughly dried and secured in the pit, after which the charge of the furnace is let into the cavity left by the wax.

Secondly; the finished figure is modelled in clay, and stuck full of brass pins just flush with its surface, which surface is now scraped away as much as the thickness required in the metal; the reduced figure is now covered with wax mixed with pitch or rosin, which is worked to the original size with all the exactness possible. The other stages are the same as in the foregoing; the metal studs or pins prevent the mould and core from falling together, and they afterwards melt, becoming a part of the metal constituting the figure.

Thirdly; the finished figure is modelled in plaster, and a piece-mould is made around it, the blocks of which consist internally of a layer of sand and loam, 1½ inch thick, and externally of plaster one foot thick. The mould when completed is taken to pieces, dried, and rebuilt in the casting pit; it is now poured full of a composition suitable for the core, the mould is again taken to pieces, the core is dried and scraped to leave room for the metal, and all is then put together for the last time, secured in the pit, and the statue is cast.

The first plan is the most wasteful of metal; the third, the least so, although it is the most costly when the time occupied is also taken into account; but it has the advantage of saving the original work of the artist.

Melting and Pouring Iron.—Iron is usually melted in a blast-furnace, or, as it is more commonly called, a cupola; although the cupola or dome leading to the chimney, from which it would appear to have derived its name, is frequently omitted, the two or three furnaces being often built side by side in the open foundry.

At the basement there is a pedestal of brickwork about 20 to 30 inches high, upon which stands a cast-iron cylinder from 30 to 40 inches diameter, and 5 to 8 feet high; this is lined with road-drift, which contracts its internal diameter to 18 or 24 inches. The furnace is open at the top for the escape of the flame and gases, and for the admission of the charge, consisting of pig-iron, waste or old metal, coke and

lime, in due proportion. The lime acts as a flux, and much assists the fusion; chalk is considered to answer the best, but oyster shells are very commonly used where they are abundant.

At the back of the furnace there are three or four holes one above the other for the blast, which is urged by bellows or by a revolving fan. No crucible is used, and as the fluid metal collects at the bottom of the furnace, the blast-pipe is successively removed to a higher hole, and the lower blast-hole is stopped with sand, which partly fuses and secures the blast-hole very effectually.

The front aperture of the furnace through which the metal is allowed to flow into the ladles or trough, is usually made sufficiently large for the purpose of clearing or raking out rapidly the fuel and slag, as the process is most laborious, owing to the excessive heat. This aperture is closed by a *guard-plate*, fixed on by staples attached to the iron-case of the furnace, in the centre of which plate the tapping-hole is made: during the time the metal is fusing, the tap-hole is closed by sand well rammed in, and this if well done is never found to fail.

Many iron furnaces are made octangular, and in separate parts bound together by hoops, so that in the event of the charge becoming accidentally solidified in the cupola, the latter may be taken to pieces for its removal, and thus avoid the necessity of destroying the furnace. There is frequently a light framing or grating above the furnace, upon which the small cores are placed that require to be dried.

In some foundries the cupolas are built just outside the moulding shop, beneath one or more chimneys or shafts, which carry off the fumes; in such cases the fronts of the furnaces are accessible through an aperture in the foundry wall, with which they are nearly flush; when the furnaces are lofty there is a feeding stage at the back, from which the charge is thrown in.

For heavy iron castings, which sometimes amount to thirty tons and upwards in one piece, reverberatory or air furnaces are also commonly used; the ordinary charge for these is four to six tons of iron, and five or six furnaces are commonly built close together, so that they may be simultaneously tapped in the production of such enormous works.*

For melting iron in the small way, good air-furnaces may be used, and also some of the blacklead furnaces, which are blown with bellows, but this is one of the processes that is not successful upon a limited scale.

Considerable judgment is required in proportioning the *charge* for the iron furnace, which always consists of at least two, and often of half-a-dozen kinds of new pig-iron mixed together, and to which new iron, a small proportion of old cast-iron is usually added. The kinds and quantities used are greatly influenced by local and other circumstances, so that nothing can be said beyond a few general remarks.

When the principal object is to obtain sound castings with a very smooth face, as for ornamental works not afterwards wrought, the soft kinds of iron containing most carbon, which are most fusible and flow easily, are principally used. But such metal would neither possess sufficient hardness, durability, nor strength, for many of the castings employed in the construction of edifices and machinery.

If the cupola contained a little hard pig-iron, but were in great measure filled with old cast-iron, which had been repeatedly melted, and had become successively harder from the loss of carbon at every fusion, such castings would be brittle, and sometimes so hard as scarcely to admit of being cut; these would be equally unfit for the generality of machinery from the opposite causes.

But the same mixture of iron will be found to differ very much according to the size of the objects in which it is cast; iron, which in a plate one-fourth of an inch thick, may be quite brittle and hard, will mostly be of good, soft, and useful quality, in a stout bar or plate of two or three inches thick. Thick castings are necessarily slow in cooling, and are seldom very hard, unless intentionally made so.

Between the extremes, (say three parts of pig-iron to one of old, or three parts of old iron to one of pig-iron,) various qualities may be selected; in castings for machinery the general aim is to obtain a strong, sound, and tough iron; mixtures of this nature which are used for iron ordnance, are called gun-metal amongst the gun-founders.

The fireman, or the individual having the management of the furnace, therefore always employs the scales in mingling the different kinds of iron, according to the magnitude and character of the works to be cast; and until the sorts in use are familiarly known, it is partly a matter of trial, and requires the same attention as the making of alloys properly so considered.†

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* A few of the modern cupolas greatly exceed the air-furnaces in effect, as they are calculated to contain upwards of twelve tons of melted iron. One of these, at the works of Messrs. Nasmyths, near Manchester, is six feet two inches diameter externally, and lined with Stourbridge bricks. It has three sheet-iron tuyeres, nine inches diameter at the mouth, the blasts from which enter the furnace at three points of the circle, and they may be slid like telescope-tubes to either of the four series of holes, as the furnace becomes gradually filled.

There are three other furnaces progressively smaller, arranged beside the first; all of which may be used separately or in combination, according to circumstances. The blast, which is under corresponding control, is obtained from two revolving fans, five feet diameter, making above 1000 revolutions per minute.

Messrs. Acramans, of Bristol, have likewise enormous cupola power; they have a series of four cupolas, in which collectively from forty to forty-five tons of iron may be melted at one time.

In some cupolas the top is contracted by a cone made of iron plate; in Yates's patent, a brick trunk is built upon the cupola, with narrow arches crossing the trunk at right angles: this economizes the heat by causing the flame and gaseous matters to be retarded, from pursuing a serpentine course in their escape.

† When the management of cast-iron was less efficiently understood, it was occasionally alloyed with five or six per cent. of shreds of copper, thrown into the ladle full of iron to produce a close, sound, strong metal, suitable to three-throw cranks for pumping machinery, and other purposes. It is said that ten per cent. of copper renders cast-iron malleable, and that alloyed with copper or tin it is less disposed to *rust:* all these alloys may be now viewed as matters of experiment alone.

It is much to be regretted that no protection has yet been found to prevent the conversion of cast-iron into plumbago, or the carburet of iron, from long immersion in sea-water, or the water of copper-mines, sewers, and other places. This, which is a most serious inconvenience in dock-works, sea-walls, and mines, arises, says Dr. Faraday, from the circumstance that the protoxide of iron, formed beneath salt-water, is soluble, and becomes washed away, thus robbing the original mass of its iron; whereas the peroxide, or ordinary rust formed by exposure to the air, is insoluble, and serves partly as a

When enough iron is melted, (the common charge being two and a half to four cwt., but sometimes above twelve tons,) the cupola is tapped in front, at a hole close to the bottom, which allows the whole contents to run out, either into ladles, or, in very large works, into channels leading directly to the moulds.*

In pouring iron, the means of conveying the melted metal to the flasks, differ with the quantity. One man will carry from fifty to seventy pounds in a hand-ladle; three to five men will carry from two to four cwt. in a double hand-ladle, or a *shank;* larger quantities, amounting sometimes from three to six tons, are carried in the crane-ladle. These all possess one feature in common, namely, their handles or pivots are placed but slightly above the centre of gravity of the ladles; they may therefore be tilted very readily, as their fluid contents, in obeying the law of gravitation, are almost neutral in the operation of tilting, which they scarcely assist or retard, unless by mismanagement the ladle is over-filled, and thus rendered top-heavy.

All these ladles are coated with a thin layer of loam, and every time before use, they are brushed over with blackwash, and carefully dried. The hand-ladle has a handle three or four feet long, with a *crutch* or cross-piece at the end, which is mostly held in the left hand; frequently the contents of half a dozen or more hand-ladles are poured simultaneously into the same flask. The shank has a single handle on the one side, and one made in two branches at the other, and together they measure six to eight feet in length; the tilting is completely under the command of the one or two men at the double handle.

The crane-ladle is carried from the furnace to the mould by the swinging and traversing motions of the crane, which is similar to those used at the iron-forges, &c., and in very large foundries, the plan of the building is divided into imaginary squares with a crane in the centre of every square, so that the ladle is walked from one to the other, even to the far end of the shop, with great facility and expedition.

The *bail*, or handle of the crane-ladle, is fixed in its perpendicular position by the *guard*, a simple bolt which prevents the ladle from being overset by accident until it has reached its destination. Two long handles, terminating in forked branches, are now fitted by their square sockets upon the swivels or pivots of the crane-ladle, and secured by transverse keys, after which the guard is withdrawn; and then two men at the ladle, two others at the crane, and one to skim the dross from the lip of the ladle, commonly suffice to manage two or three tons and upwards of fluid iron, with great ease and dexterity.†

The observations offered on page 250, respecting the temperature of the metal suitable to different brass works, might be here in a great measure repeated; namely, that the smallest castings require very hot metal, and a gradually lower temperature is more suitable to works progressively heavier, to avoid their becoming sand-burned or rough on the face, from the partial destruction of the mould.

When cast-iron is very hot, the metal scintillates most beautifully, far more vividly than a mass of wrought-iron raised above the welding heat; as the metal cools, the sparks become intermittent, and at last the metal remains entirely quiet, excepting a multitude of lines vibrating in all directions, as if the surface were covered with thousands of wire-worms in great activity; this effect lessens until the metal solidifies. The softest iron shows most of this play of lines, or is said to *break* the best.

Iron castings are generally much heavier than those of brass, and the melting heat of the metal being considerably higher, the quantity of gas generated is very much greater; additional care is consequently required to provide for its escape, or the explosions are much more violent. The sand is punctured at many places with a fine wire, before the removal of the patterns; sometimes also more coarsely as soon as the metal has become solidified. The gases issuing from the filled moulds are often lighted, either by the red-hot skimmer, or by a torch of straw with which the moulds are flogged: this lessens the accumulation of gas and the consequent risk of accident.

The pouring of very large objects in *open* moulds, such as plates, beams, and girders, is a very beautiful and grand sight. The metal is led from the furnace, through a gutter lined with sand, into a large trough or *sow*, the end of which is closed with a *shuttle;* when the sow is full, the shuttle is raised; this allows the metal to flow very quickly into the mould, but enables it to be kept back should it be unnecessarily hot; the castings made in open moulds are generally covered up with sand as soon as the metal is set.

The above, and the casting of smaller objects, such as flat plates in open moulds, may appear amongst the most certain modes of procuring sound castings; but unless the air be well *drawn* from the lower surfaces, they will become honey-combed or full of air-bubbles. This defect is avoided by making the sand-bed sufficiently porous, and pricking it with many holes just below the surface, to serve as horizontal *air*-drains.‡

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defence to the metal beneath. When first raised from the sea-water, the plumbago becomes exceedingly hot from the action of the atmosphere; it may be cut with a knife like an ordinary pencil.—Minutes of Conversation, Inst. Civ. Engineers, 8th Feb. 1842.

* The furnace is not unfrequently tapped whilst the charge of metal is being melted, and in such cases when the required quantity has been removed into the ladles, the fireman restops the tap-hole by a conical plug of clay on the end of a wooden bar; the process is called *botting*, and requires a dexterous hand, or the whole contents of the furnace may escape.

† Mr. Nasmyth has added to the pivot of the large crane-handle, a tangent-screw and worm-wheel, by which it may be gradually tilted by one man standing directly in front at any convenient distance; and another man skims the metal by a kind of throttle-valve coated with clay, which sweeps into the lip of the ladle, and keeps back the sullage: the axis of the skimmer is continued as a long rod, at right angles to the first, and also terminating in a cross. By these arrangements any precise quantity of metal can be delivered, and the risk of accident scarcely exists.

‡ In casting lead, tin, &c. on a flat metallic plate, the formation of air-bubbles is lessened by placing a sheet of dry paper on the plate; it appears to keep down any little bubbles of air or vapor, and to provide a thin channel for their escape.

But the most perfect example of a porous mould is that invented by Lord Rosse, to avoid the formation of air-bubbles in those speculums which are cast in open moulds. The plate, or bed of the mould, consists of a great number of slips of hoop-iron placed edgewise and in contact; they are screwed tight within a frame, and are then turned in a

A far greater number of works are cast in *close* moulds, and in the horizontal position; the proportionate quantity of metal is carried to them in ladles: skimmers are held to the lips of the moulds at the time of pouring, to keep back all the sullage or dross. The number, position, and height of the runners, are determined by circumstances; generally not less than two apertures are provided, the first for the entry of the metal, the second for the escape of the air, and to allow the metal to *flow through* the mould and carry off the sullage.

Sometimes in heavy castings, in addition to the runners, one or more large heads or *feeds* are made at the upper part, to supply fluid iron as the metal shrinks in the act of solidifying; and in some such cases the feed is *pumped*, by moving an iron rod up and down in the feed to keep the metal in motion, so that for a time the metal may freely enter and the air escape, to increase the general soundness of the mass. The pumping should, however, be discontinued the moment the metal begins to stiffen and clog the iron rod, or in other words to crystallize, otherwise mischief instead of benefit will accrue.

Works which are required to be particularly sound, as some cylinders, pipes, shafts, and plungers, are cast vertically; the moulds are sunk in the earth, and well rammed to enable them to withstand the great pressure of the fluid column, without becoming strained or bursting open. Such objects are moulded and poured with a head, or an additional portion about one-third the length of the finished casting, as mentioned in respect to brass guns.

In pouring cylinders of tolerably large size, the metal is conducted from the sow through two sunk passages with side branches, entering the mould in the direction of tangents about one-third from the bottom; these keep the metal in circulation, and assist the rise of the sullage. Cylinders are also poured through holes in the loam-cake, other apertures being always provided in it for the escape of the air. Beneath the iron plate upon which the mould is built, is placed a central mass of haybands, in order that the air may have free passage to collect, and then to escape upwards to the surface of the earth, through one, two, three, or more internal or external tubes, as the case may be. The thick cylinders for hydrostatic presses are closed at one end, and those cast with the mouth downwards require an air-tube bent at each end, to lead from the core beneath the casting to the surface of the earth; the gas drives out in a stream, and is immediately ignited like a great torch: others prefer casting them with the mouth upwards, in order that less risk may exist of locking up air within the casting.

For the very heaviest works, the three or four furnaces are usually tapped at the same moment; the stream from every one is conducted through a sand-trough, and they all unite in one great trunk leading to the mould.

In pouring some of the largest cylinders, the trough is led entirely round the top of the loam-mould; and from the circular channel, sometimes as many as thirty runners, every one of which is stopped by a shovel held by a man or a boy, descend to the mould, and as many air-holes are made between the ingates. When the foreman sees that all the furnaces are in full run, and that the channels are well supplied, he gives the word, "*up shovels;*" they rise at the instant, and allow the molten stream to deposite itself in its temporary resting-place.

At the time the cylinder is poured, all the precautions explained in the note, p. 257, are necessary to give the mould sufficient strength to resist the pressure of the fluid metal; but as soon as it becomes set, the conditions are altered, and this resistance must be removed from the inner surface, that the cylinder may shrink, in cooling, without restraint or fracture. Accordingly, after three or four hours' time, all the diametrical iron stays are knocked away by a vertical weight or monkey, and men descend by iron ladders into the cylinder, to break down the brick core. The heat is so terrific, that they can only endure it for a minute or so at a time, but still the precaution is imperative: and even in comparatively small castings of hollow objects, such as cylinders, pans, and boxes, it is desirable to break down the cores, to prevent the castings from *scoring* or breaking.

Although some iron castings employed for bridges, girders, and even for machinery, require the enormous quantities of iron referred to, on the other hand this useful metal is employed for exceedingly light and beautiful castings, abundant examples of which may be seen in the Berlin ornaments and chains.* The links of most of the Berlin chains are connected with wrought-iron wire, but Figs. 841, 842, represent a chain made entirely by the process of casting.

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lathe to the required curve; by this arrangement interstices exist at nearly every point through which the air may escape downwards.

Speculum metal is perhaps the most untractable of any of the alloys, and it serves to illustrate in a most striking manner many of the effects that occur in castings generally. Small speculums are cast in sand; as soon as they are set, the sand-core is pushed out of the aperture, in such as are intended for Gregorian telescopes, to enable them to contract without fracture, and the red-hot disk is surrounded by ignited wood-ashes or any very bad conductor, to delay the cooling.

These precautions entirely fail with large speculums, as their margins solidify the first, and from the absence of ductility, the central parts tear away in the act of contraction, and the mass becomes rent or flawed. Lord Rosse considered this fracture would be avoided by cooling the speculums in *uniform layers* from below upwards, or as it were in infinitely thin laminæ, and he therefore first employed iron moulds which were cooled by a stream of water projected against their under surfaces; this partially answered with small speculums, but with those of 18 inches diameter it almost always failed, as the mould cracked before the metal was congealed. A general source of failure was the non-escape of air; this caused the lower surface to be full of air-bubbles, which it was tedious to grind out.

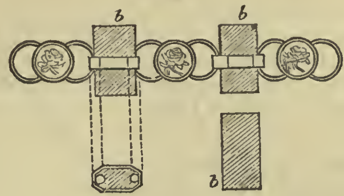
The plan ultimately adopted was the porous hoop-iron mould, with a marginal ring of sand; the mould was heated to about 212° F.; it was filled very quickly, and the moment the metal was solidified, it was drawn into an annealing oven previously heated to about the same temperature as the casting; so that for small reflectors of nine inches diameter, the cooling might be extended over about three days, and for large ones of thirty-six inches diameter, over about fourteen days; with these precautions the process was uniformly successful.—*See* Trans. Royal Soc., 1840, pp. 510, 11. The whole of the paper "On the Reflecting Telescope," pp. 503 to 527, is quite a study for those interested in the construction of telescopes, and possesses nearly the same interest for the general mechanist.

* We have seen some of these gems of art in the condition in which they left the moulder's hands, and also a portion of the sand employed: notwithstanding the minute size of the castings, some of them are quite hollow, as if stamped out of thin steel metal.

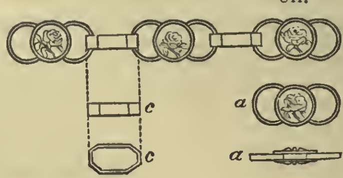
Professor Ehrenberg says, that the iron employed for them is made from a bog-iron ore, and that the sand is a kind of tripoli, also containing iron: both are entirely constituted of various kinds of animalcules, several of which are found,

Its length is 4 feet 10 inches, it consists of about 180 links, and weighs 1$\frac{5}{8}$ oz. avoirdupois. It was thus made; the larger links *a a* were first cast separately; a solid model of the chain about eight inches long, with core prints, as in fig. 842, was then moulded; the links *a*, previously smoked to prevent the adhe-

842.



841.



sion of the metal, were first laid in the mould, and afterwards the sand-cores *b b*, and a separate runner was made to every one of the small links *c c*, so as to unite the whole when poured.

CEMENT. See Mortar.

CENTRES. See Bridges.

CENTRE OF GRAVITY. The forces with which all bodies tend to fall to the earth may be considered *parallel;* hence, every body may be considered as acted on by a system of parallel forces, whose resultant may be found; and these forces, in all positions of the body, act on the same points in the same vertical direction. There is, therefore, in every body a point, through which the resultant always passes, in whatever position it is placed. This point is called the *centre of gravity* of the body. The centre of gravity of a uniform cylinder or prism is in its axis, and at the middle of its length; of a right cone or pyramid it is also in the axis, but at one-fourth of the height from the base.

To ascertain mechanically the position of the centre of gravity of a body (Figs. 843, 844). Suspend the body by a string from the point Q (fig. 843), and let Q R be the direction of the line when plumb; now the only forces by which the body is acted on are the weights of its different parts and the tension of the string; the former may be replaced by their resultant. Since the body is in equilibrium, the resultant and the tension must act in opposite directions, and in the same straight line Q R. But as the resultant must always pass through the centre of gravity, the centre of gravity must be in the line Q. R. Mark the direction Q R, and suspend from another point P. The centre of gravity, by similar reasoning, must be

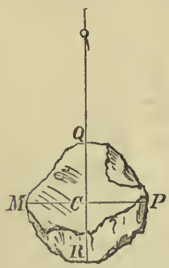


Fig. 843.

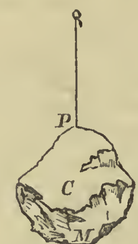


Fig. 844.

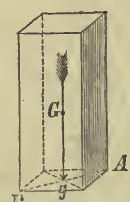


Fig. 845.

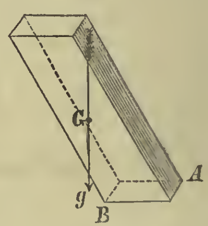
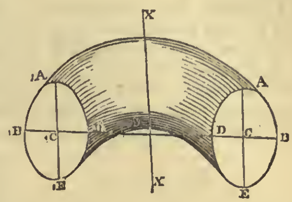


Fig. 846.

in the line P M, and can only be, therefore, at the intersection C of the two lines. Or, balance the body upon the edge of a bench till it be just on the point of falling off; then mark a line along it by the edge of the bench; do the same in another position of the body, and the centre of gravity in the body will be in a line and perpendicular to the point of intersection. The centre of gravity of a straight line lies in its middle. For bodies whose points are regular and the substance homogeneous, the centre of gravity is determined by certain geometrical rules. The centre of gravity of a cylinder is evidently the middle of its axis; and whenever a body possesses a *centre of figure*, *i. e.* a point so situated that every plane which can be conceived to pass through it must bisect the body, this point is the centre of gravity (supposing the body to be of uniform density). Moreover, whenever a body has an *axis* of figure, that is, a *line*, every plane passing through which bisects the body, then the centre of gravity must be somewhere in that line. Consequently, when the body has more than one such axis, the centre must be found at their intersection. Every *pyramid* or *cone* has its centre of gravity at $\frac{1}{4}$ of its height, from the base,—every *paraboloid* at $\frac{1}{3}$ of its height,—every *hemisphere* or *hemispheroid* at $\frac{3}{8}$,—a *hemicylinder* at ·4244 of its radius from the axis of the cylinder. To find the distance of the centre of gravity of any *segment* of a *disc* or *cylinder*, from the axis, divide the cube of the chord by 12 times the area of the segment. To find the same in a *sector*, multiply twice the chord by the radius and divide by three times the arc. The centre of gravity is not necessarily *in the body*, but may be in some adjoining space. This is obviously the case with a *ring*, an *empty box*, and, in general, any hollow vessel.

Centrobaryc theorem, or *Method of Guldinus.* These centres of gravity of lines or surfaces (which can be found approximately by experiments on thin wires or plates) afford an easy means of solving certain useful problems in mensuration, the solution of which deductively (or by pure mathematics) would be extremely difficult, if not impossible. For instance, any *solid of revolution*, however complex or irregu

lar its outline, may have both its solidity and its superficial contents found by the following very simple methods. Let 847 be the solid, and ABDE its half sections, or that plane figure which, in revolving round the line AE as an axis, would require a space equal and similar to the solid—or, as it is commonly expressed, would *generate the solid.* Cut out this figure in some thin substance of uniform thickness, and by suspending it as above described, find its centre of gravity, which we will suppose to be C. Now the volume of this solid is equal to the product of the area ABED + into the circumference described by the point C, (which circumference will of course be found by applying the well-known multiplier, 3·14159, &c. to twice the distance of C from the axis *c*. Again, to find the *surface* of the solid or of any portion of it, as formed by the revolution of the whole or any portion of the curve ABED, bend a wire into the form of that portion required. Find its centre of gravity, then the surface generated by the revolution = its length + the path described by its centre of gravity. A body, when placed on a horizontal plane, will fall over unless the vertical line passing through its centre of gravity fall within the base; thus in Fig. 845, the body will stand firmly, whereas in Fig. 846 it must manifestly tumble over Persons who carry loads adjust their position so that the common centre of gravity of the load and of the body shall fall within the area bounded by their feet. The lower the centre of gravity, and the more extended the base, the more stable the position of the body, and the more difficult to be overturned.



CHAIN, in surveying, is a lineal measure, consisting of a certain number of iron links, usually 100, serving to take the dimensions of fields, &c.: at every tenth link is usually fastened a small brass plate, with a figure engraved upon it, or else, cut into different shapes, to show how many links it is from one end of the chain.

CHAIN CABLE. Iron cables were first proposed as a substitute for hempen cables by Mr. Slater in 1808, but they were first employed by Capt. Brown of the W. I. Service, in 1811. It was at first supposed by the inventor, that a certain degree of elasticity must be given to the chain cable, so that a sudden strain should not break it. With this view the links of the chain were twisted about half way round, so that when the strain took place, the links by yielding a little, or partly untwisting, might produce an effect somewhat similar to the natural elasticity of hemp. It is found, however, that when a certain length is let out, the weight of the long catenary curve affords an elastic tension, or play to the ship, under the pressure of the wind. The dead strain upon the anchor is thus reduced, and sudden strains upon the flukes or arms, thus in a great measure obviated. The best iron cables are chains made of links, bound and braced by rods across the middle. It is found that the ends of the links wear out much quicker than the sides, and they are therefore made considerably stouter at the ends than in the middle. Mr. Hawkes, iron manufacturer, patented an invention in 1828, for thickening the ends of the links at the point where the greatest friction, and wear takes place. The improved links are formed from cylindrical bars, formed either by rolling, swageing, or stamping with projections or swells placed at such distances on the bar, as to come exactly opposite each other when the bar is turned into a link, by which means the ends are made thicker than the sides. The best form of links is an oval with a broad headed stay in the middle, to prevent it from collapsing or shutting up, under a heavy strain. Another advantage of this stay is, that it prevents the different links from entering each other, and thereby entangling the cable.

Size of Bolt.	Proof of Bolt.		Proof of Chain.	
Inches.	Tons.	Cwt.	Tons.	Cwt.
$\frac{1}{2}$	5	7	8	11
$\frac{5}{8}$	8	7	13	4
$\frac{3}{4}$	12	1	19	5
$\frac{7}{8}$	16	4	26	5
1	21	8	34	5
$1\frac{1}{8}$	27	2	48	15
$1\frac{1}{4}$	33	10	53	11
$1\frac{3}{8}$	40	10	65	0
$1\frac{1}{2}$	48	4	77	0
$1\frac{5}{8}$	56	11	90	10
$1\frac{3}{4}$	65	12	105	0
$1\frac{7}{8}$	75	6	120	10
2	85	14	137	0
$2\frac{1}{8}$	96	15	155	0

As it is frequently necessary to sever the cable, provision is made for the purpose, by means of a bolt and shackle at every one or two fathoms, so that by striking out the bolt the cable is parted with ease. See Proving Machine.

The accompanying is a table of the breaking proof of chain cables, and of the iron used in their construction.

CHAIRS. See RAILROADS.

CHARCOAL. See IRON.

CHIMNEYS. See BOILERS.

CHISELS. See CUTTING TOOLS.

CHRONOMETERS. See WATCHES.

CHAIN PUMP. A machine for raising water; it consists of a series of pistons or round plates of metal, set at certain and regular intervals on an endless chain, which nearly fit the calibre of the tubes in which they work. Putting the chain in motion, supposing the bottom of it to dip into the water of a well, each piston will enclose above it a certain quantity of water, and bear this water to the top, where it overflows into a cistern prepared to receive it.

CHAMFER. An edge or arris, taken off equally on the two sides which form it, leaves what is called a chamfered edge. If taken off more on one side than the other, it is said to be splayed or bevelled.

CIRCULAR SAWS. See SAWS.

CIRCULAR SAW *for Cutting Veneers.* The object of this machine is to cut up logs of fine wood into slices or leaves for purposes of veneering. From ten to sixteen of these slices may be cut from an inch of wood; and considering that the logs are from 9 to 36 inches broad, some idea may be formed of the nicety of the operation, and of the steadiness and rigidity of parts required in the machine for the efficient discharge of its functions.

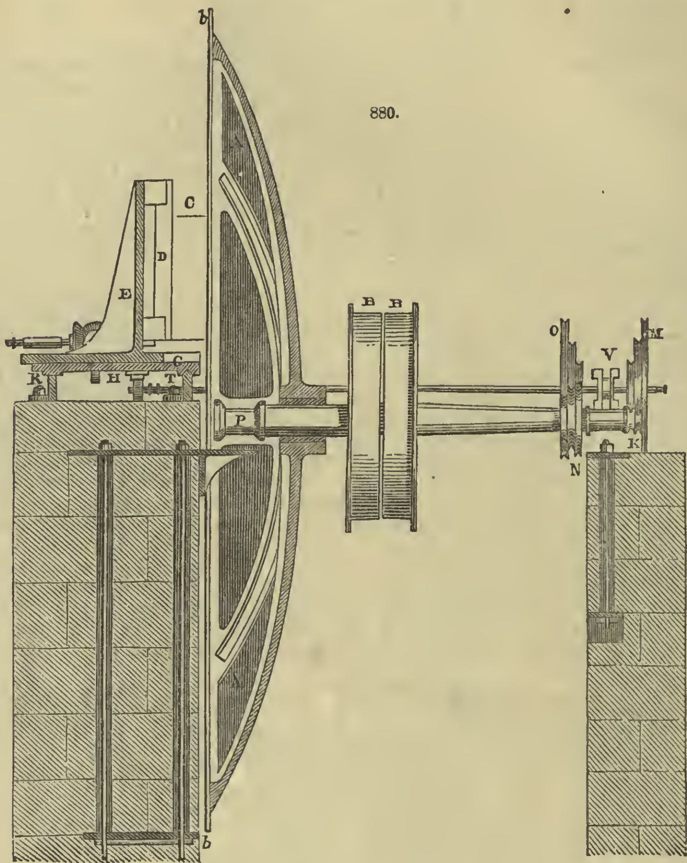
The principal feature of the machine is a circular saw, marked *bb* in the cuts, which is built in segments upon a strong, rigid, cast-iron frame A, which, it will be observed from the sections and the plan, consists of a series of arms radiating from a central eye, dished in form, like an ordinary carriage-

wheel, and flanged on the hollow side, to secure rigidity; these arms terminate in a broad, flat ring, upon which the segments of the saw are fastened by means of short countersunk screws, as exhibited in Fig. 882. The saw-frame, as it may be termed, is hung upon a strong shaft P, which runs in bearings located on wall-plates, secured to a foundation by holding-down bolts. Upon the same shaft are hung the driving-pulleys B B, whence the motion of the machine is derived.

While the axis of the saw-frame remains stationary during the operation of the machine, the log of wood C, which is being cut up, is urged forward against the saw by a gradual progressive motion, being fixed for the purpose on a sliding carriage D E G, moved by a self-acting apparatus.

First of all, the carriage runs upon two parallel rails T R, bedded on two longitudinal square tim-

880.



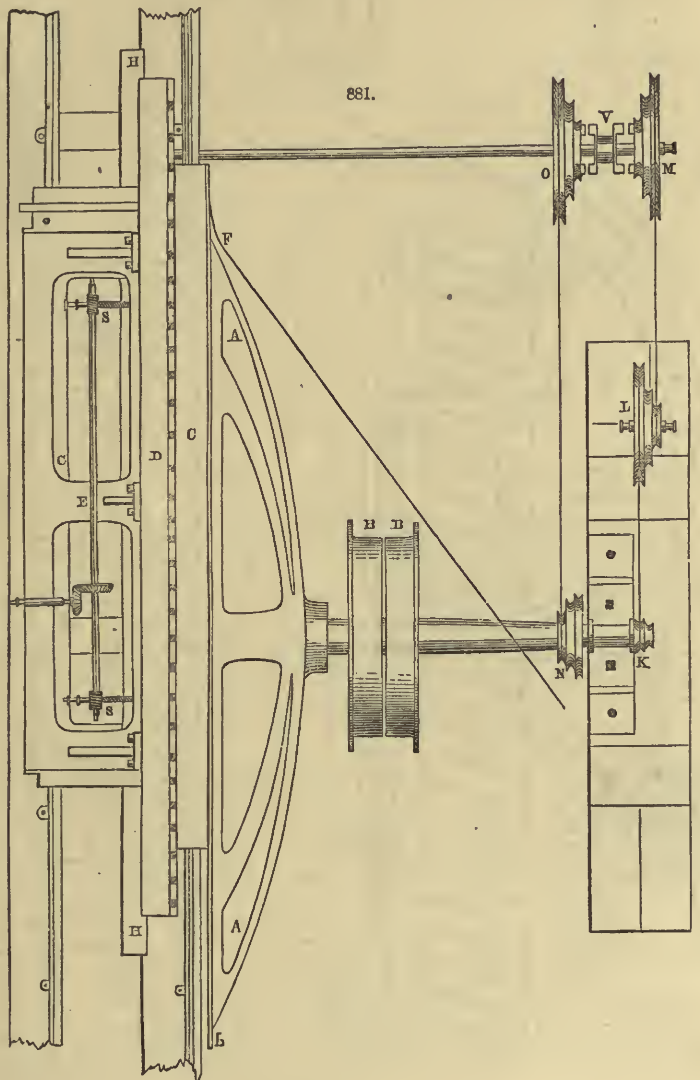
bers, and firmly bolted down to them. The lower part of the carriage G, slides on these rails at three surfaces of contact on each rail, as may be seen in Fig. 882. The upper part of the carriage E is held down to the part G by means of dovetail bevel surfaces, where a broad piece of metal is introduced between the snug cast on the end of the piece G and the bevel edge of the piece E, and bolted down to G, thereby holding down the piece E to G—admitting also of a transverse sliding motion of the piece E; (see Fig. 882.) From the piece E, three flanged arms are erected, to which is bolted the timber frame D, on which is immediately sustained the log C. The frame D consists of two longitudinal square timbers, the lower one of which, as shown in Fig. 880, rests upon short flanges projecting from the faces of the arms of the piece E, and is thus prevented from sliding down; these timbers are connected by a series of spars, checked at both ends into the timbers. The spars are finished flush on their exterior surface, on which they receive the log C, which adheres to them by means of a film of glue interposed. The spars are set at an inclination backwards, as they are thus more directly in the line in which the strain comes upon them.

The self-acting motion for moving the sliding carriage, and thereby feeding the saw, is driven from the main shaft. A rack H fixed on the under side of the carriage, is driven by a pinion on the end of the horizontal shaft T, Fig. 880, upon which the triple-grooved pulleys M O run loose, ready to be catched alternately by the sliding-clutch V. The pulleys M are driven by the pulleys K on the end of the main shaft, the motion being reduced by means of the intermediate pulleys L. The pulleys O are driven directly by the pulleys N on the main shaft. The pulleys K L M are those which feed the saw, the band K L crossing itself, and L M being an open band. The pulleys N O reverse the motion

of the log-frame, and carry back the log to prepare it for a succeeding cut. Three different speeds are provided in these pulleys.

The motion for feeding the saw transversely—that is, for shifting the log in the direction of its breadth, in setting it for another cut—is effected by the screws S S, the bearings of which are fixed on the sole G, and their screwed parts working in nuts fixed on the piece E. On these screws, worm-wheels are fixed, driven by worms on a horizontal shaft, which again is driven by hand, by means of a pair of small meter wheels—all which is represented in the plan, Fig. 881. The lateral motion of the piece E is directed by the bevel surfaces between which it is confined.

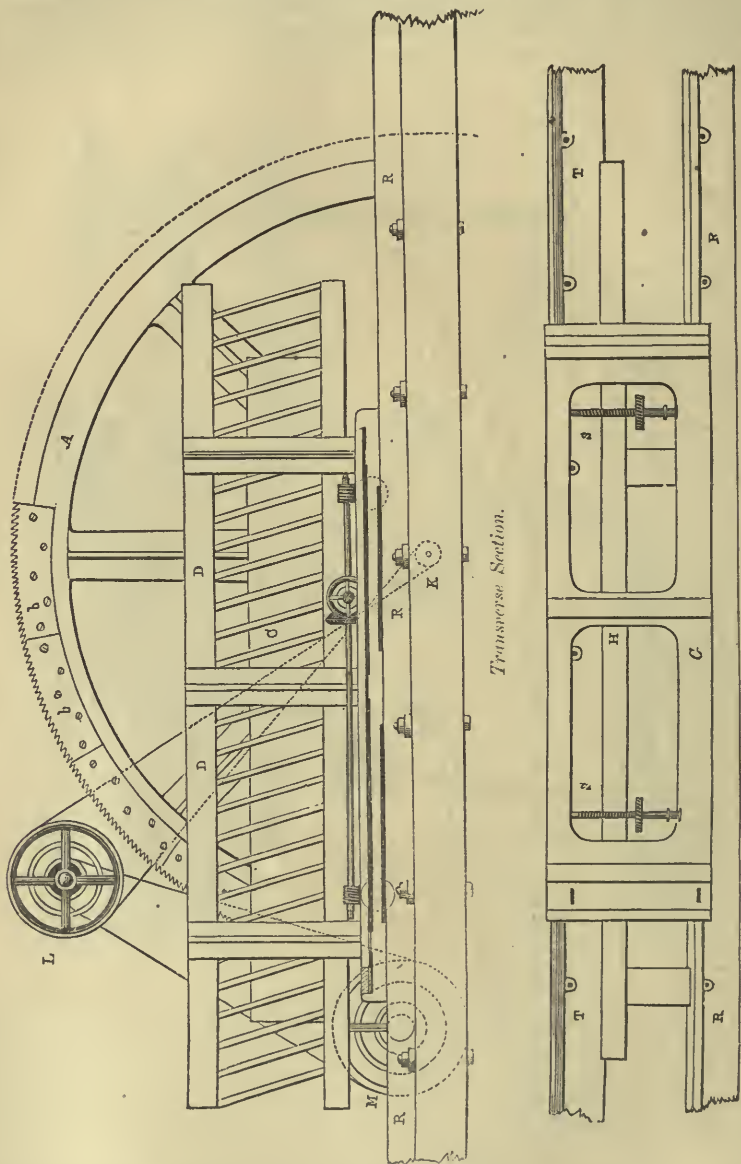
881.



Action of the Machine.—The log being fixed to the frame D E, and the end of it adjusted in contact with the edge of the saw, by means of the longitudinal and transverse sliding-surfaces already described, the clutch V is geered with the pulleys M, the driving-bands being shifted to the proper speeds. The driving-belt is then shifted to the driving-pulley B, and the saw is caused to revolve at a high speed, the self-acting motion at the same time urging forward the log. The veneer, as it separates, glides off the back of the saw-frame, as shown at F in Fig. 881, and, when cut off, is carried away. The clutch V is then reversed into geer with the pulleys O: thus the motion of the sliding-carriage is reversed, and the log is returned to its first position in front of the saw. The clutch is then entirely disengaged, and the transverse motion is applied to the frame D E, by which the log is shifted in front of the saw, in readiness for the next cut. The clutch V is now engaged with the pulleys M, and the process is repeated as already described.

The speed at which the saw is driven is about 180 revolutions per minute, which with a diameter of twelve feet, gives a velocity of 6784 feet in that unit of time. The feed-motion for that velocity is about ¾ inch for every revolution of the saw, making 11¼ feet per minute of veneer cut. The feed-motion is, however, modified according to the quality of the log under operation: often it does not exceed a half of that stated; and in some mills the velocity of the saw is also less.

882.



Transverse Section.

Plan of the Lower Carriage.

Lateral References.—A, the saw-frame, with the saw *b b* attached to it.
B B, the fast and loose pulleys on the saw-frame shaft.
C, the log which is to be cut into veneers.
D, the timber-frame to which the log is attached.
E, the cast-iron frame to which D is bolted, which slides laterally under dovetail surfaces.
F, the veneer as it comes from the saw, gliding off the saw-frame.
G, the lower part of the sliding-carriage, which slides longitudinally on rails laid on timbers.
H, the rack attached to the sliding-carriage, and driven by a pinion on the shaft of the feeding apparatus.

K, grooved pulleys on the end of the main shaft, for driving the feed-motion.

L, intermediate pulleys, driven by the pulleys K.

M, pulleys loose on the pinion shaft, driven by the pulleys L.

N, pulleys on the main shaft, for reversing the motion of the log.

O, pulleys loose on the pinion shaft, driven by the pulleys N.

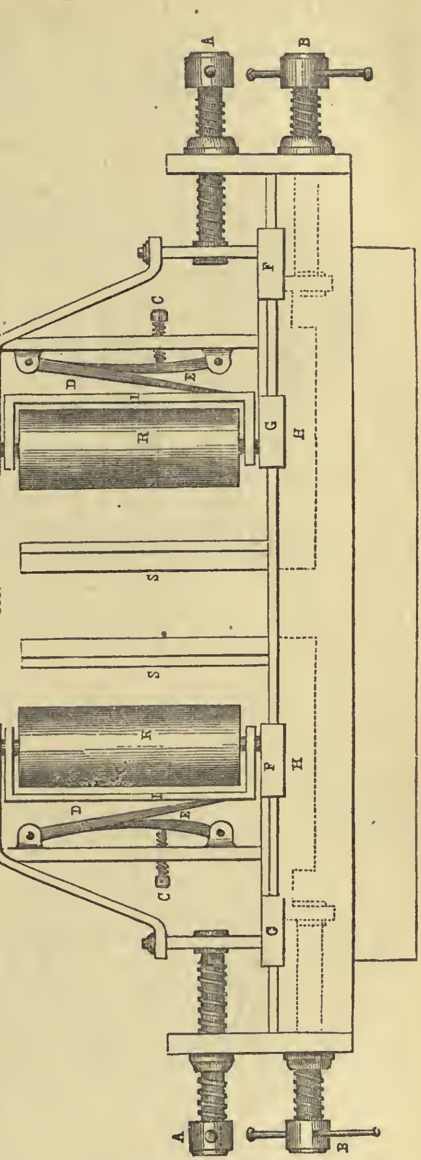
P, the saw-frame shaft.

R T, longitudinal slides on which the sliding-frame is moved.

S, screw and wheel motion for shifting the log-frame laterally.

V, the clutch carried round with the shaft on which it slides, so that it may be put in geer with the loose pulleys M O, alternately.

Saw-mill Rollers for Planks.—Fig. 883 represents an arrangement for steadying the planks or logs as they are moved forward in saw-mills.



883.

A A, are adjusting-screws, working in nuts fixed on the frame of the machine, for setting the roller-frame against the logs.

B B, are adjusting-screws for setting the plank-frame H S.

C C, pinching-screws, acting by the intervention of levers upon the rollers.

D D, levers jointed to the roller-frame, transmitting the pressure of the screws C C to the rollers.

E E, spring-levers intermediate between the screws C and the levers D.

F G, F G, the soles of the roller-frames, guided in their traverse motion by dovetail surfaces upon H H.

H H, the plank-frames, into the ends of which are inserted the screws B B.

I I, clutch-frames, through which the journals of the rollers pass; they transmit the pressure of the levers D D to the rollers.

R R, the rollers which press the planks against the uprights S S, and steady their motion; the ends of their journals move in grooves in the framing F G, F G.

S S, uprights rising from the plank-frames H H, against which the planks are held by the rollers.

CLOTHING BOILERS AND CYLINDERS, *saving fuel from.* See MANAGEMENT OF ENGINES.

CLOTH-SHEARING MACHINE. Invented by Milton D. Whipple, of Lowell, Mass., for shearing cotton cloth, or preparing it for being printed.

Fig. 884 denotes a top view of the machine; Fig. 885 is an elevation of one side of it; Fig. 886 is an elevation of the other side of it; Fig. 887 is a central vertical and longitudinal section of it; Fig. 888 is an elevation of the front end; and Fig. 889 is an elevation of the rear end.

The machine to be described is calculated to remove from the surface of calico or cotton cloth the furze, nap, knots, or other matters which are usually taken off by the process of picking by hand, and singeing by hot rolls or plates, or the flame of gas.

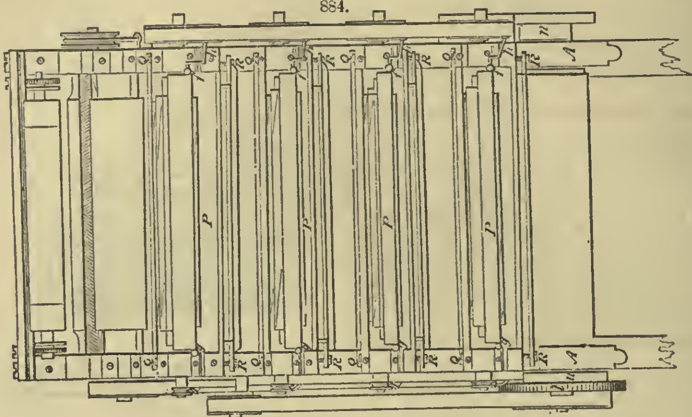
Mr. Whipple does not confine his invention to the shearing of cotton cloth alone, as it may often be used to good advantage on many other thin cloths, such as mouslin de laine, for instance.

In the drawing, A denotes the frame-work of the machine constructed of iron, wood, or any other suitable material; B is the driving-shaft extending across the frame, and made to run in proper boxes; C is a fast pulley, and D a loose pulley arranged on the shaft, motion being given to said shaft by the belt, from the driving power being made to operate on the fast pulley; E F G H are four series of revolving helical shearing-cutters applied to, or arranged respectively on horizontal shafts I K L M, whose journals are supported in boxes N N N, &c. Beneath each of these series of cutters is one of a series of blades or horizontal knives O O O, &c., which is attached to a head-piece or holder P. The ends of the said head-piece have adjusting-screws Q R, Q R, applied to them in such manner as to admit of the correct adjustment of the holder P, and blade O, with respect to the rotating helical cutters over and in advance of them. At some distance in front of each of the blades O O, is a rule or ledge S, whose

upper edge is placed somewhat above the under surface of the knife or blade O; the position of said rule S, and the top of it with respect to the cutters and blades, being as seen in the drawings. Each of the series of revolving cutters has a pulley T fixed on it. There is a driving-pulley V on the driving-shaft. A belt V passes around the said pulley V, and the two middle pulleys T T, as seen in Fig. 885. It is by means of the said pulleys and belts, that the several series of helical cutters are put in revolution.

A cylindrical brush X is placed in advance of the first rule S, and so as to bear against the cloth Y

884.



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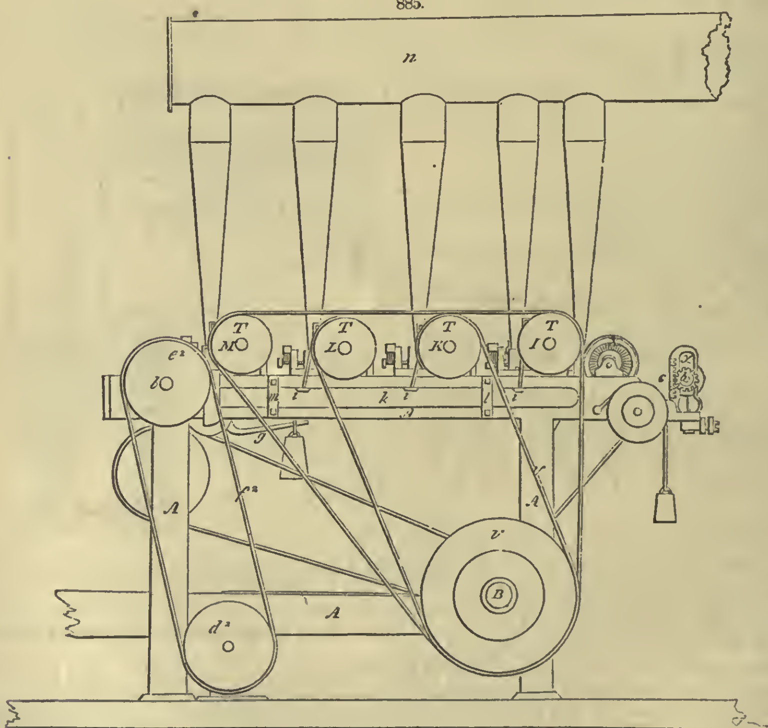


as it passes from the under surface of a friction-roll on cylinder Z to the top of the first rule S; the said brush is revolved by a belt, which passes around two pulleys b c, the former of which is fixed on the driving-shaft, and the latter on the shaft of the brush x. In the rear of each blade O, and between it and the rule or ledge S, directly in rear of it, is a long transverse horizontal brush z, which rests on the cloth, and removes any superfluous lint, and lays the nap of the cloth as it passes underneath in the proper direction to be acted upon by the cutters in rear of it; e and f are a pair of drawing-rollers arranged at the rear end of the machine, as seen in Fig. 887. The lower one has its journals sustained

in boxes, applied to the ends of two weighted levers *g*, H, by the action of which it is pressed against or towards the upper roller.

The upper roller has a geer-wheel *i* fixed on its shaft; the said geer-wheel is made to engage with a toothed pinion K fixed on a shaft *i;* on said shaft *i* is a pulley *m*, around which a band *n* passes to a pulley O fixed on the driving-shaft. By means of the pulley, belt, and geers, the upper drawing-roller receives the motion.

A stretching-bar P is arranged at the front end of the machine, and directly over the roller *z*. The upper edge or surface of the bar has grooves or flutes made diagonally across it, those on the side of the centre of the bar being caused to run in a direction opposite to those on the other, as seen in the figures, the object of this bar being to stretch the cloth in lateral directions.

When the cloth first enters the machine, it passes over a cylindrical rocking-bar *q*, (see Fig. 888,) which is supported, so as to rock or vibrate laterally on a post *r*, made to rise upwards from a transverse bar S. From the centre part of each end of the bar, one of two rods or journals *i u* projects, as seen in Fig. 890, which denotes a vertical and longitudinal section of the bar, and parts connected with it. On each of the journals one of two pulleys *v w* is placed, and revolves; each of said pulleys being of a diameter corresponding to that of the cylindric bar *q*. The external curved surfaces of the pulleys are made rough by having sand-paper, or sand or emery glued to them, and each of said pulleys has a neck or hollow shaft *x* extending from it, and through a vertical groove *y*, made in one of two plates or standards *z a*. A small geer-wheel *b* is fixed on each hollow shaft *x;* the said geer-wheel being made to engage with a vertical toothed rack *c*, affixed to the standard, as seen in Figs. 885 and 886. The peculiar object of the said rocking-bar and mechanism applied to it, is to cause the cloth, as it rises up from the pile on the floor, to be delivered centrally upon the front series of helical cutters; or in other words, so that one of its selvages shall be at the same distance from the adjacent end of the series of cutters as the opposite selvage is from the end thereof adjacent to it.

The length of the rocking-bar is made equal to, or somewhat greater than the width of the piece of cloth: when the piece is drawn through the machine by the action of the drawing-rollers, it is made to pass over the rocking-bar. If either selvage or edge of the piece, while so in motion, should happen to project at any time beyond the contiguous end of the rocking-bar, and upon the surface of the adjacent pulley *v* or *w*, it will cause said pulley to turn on its journal; the consequence of which will be, that the toothed pinion *b* will be made to revolve by it; which motion of the pinion will cause it, by its connection with the rack into which it goes, to rise upwards and tilt the rocking-bar into an inclination to the horizon, thereby inducing the cloth to move laterally on the rocking-bar, or towards the pulley at its opposite end. Should it by chance run over the last pulley, a contrary action will occur, and the rocking-bar will be tilted in an opposite direction, and so as to induce the cloth to slide or move towards the other pulley. The apparatus is thus self-acting, and operates with all the desired regularity and precision to introduce the cloth centrally into the machine.

Directly over each of the series E F G H of revolving helical cutters is an oiling apparatus, which consists of a strip of cloth *d*, affixed to a long bar *e*, whose ends have journals which are supported and move in the tops of posts or standards *f* G. One of the journals of each of the bars e^1 e^1, &c., has an arm *h* extending downwards from it, and passing through one of a series of staples *i i*, &c., driven into a long slide-bar K.

This slide-bar is sustained by bearings *l m*, fastened to the side of the frame A, and its rear end rests against a cam *n*, fixed on the shaft of the upper driving-roller. The said cam during part of its rotation forces the slide-bar forward, and longitudinally, in such manner as to move all the arms *h h* simultaneously, and thereby cause all the strips of cloth to rise above their respective series of cutters. The retraction of the bar may be effected by a spring properly applied to it, the said retraction causing all the strips of cloth to descend upon the cutters. Each strip being saturated with oil, will, when it is carried in contact with the knives or cutters, lubricate their edges.

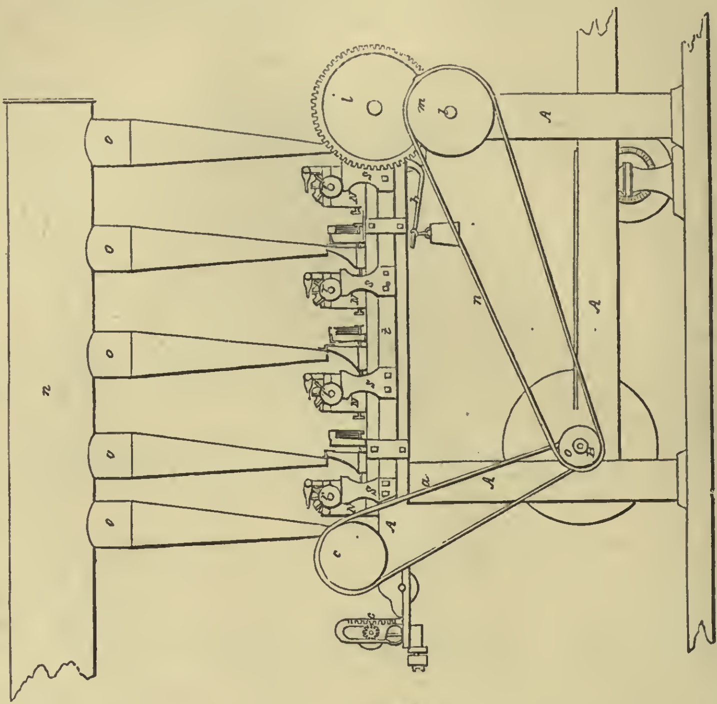
The next portion of the machine to be described is that by which the lint and extraneous matter, removed from the surface of the cloth by the helical cutters, are taken from the machine. For this purpose is placed above the frame A, a large pipe or hollow cylinder or vessel *n*, one end of which should be stopped up while the other should connect with an air-exhausting apparatus of some proper kind.

From this pipe others, O O, &c., extend downwards, and open respectively in vertical, triangular, or other proper-shaped vessels P P, each of which is placed respectively just in rear of the cutters and rotary brush, and is open at bottom, and shaped and made as seen in the drawings.

Each of the bars to which the blades O O, &c., are attached is curved upwards, as seen at *q*, so as to direct the lint and the conductors P P. Now when air is drawn out of the pipe *n* by the exhausting apparatus, an atmospheric current will rush up each of the vessels and pipes extending downwards from it. In the passages of said currents into the adjutages of the conductors P P, and through the same, and pipe O, they will carry with them the lint and extraneous matters removed by the cutters and rotary brush.

In order that the cutters may perform their operation on the cloth in a proper manner, a reciprocating lateral movement as well as a rotary movement may be given to them: this is effected in the following manner.

On each cutter-shaft is a grooved pulley r^1, into the groove of which the upper end of one of four vertical plates S S, &c., is inserted, the said plates being secured to a horizontal slide-bar *t*, which is arranged and operated by a cam, and a retracting spring, in substantially the same manner as is the slide-bar K, hereinbefore described. The upper end of each of the plates S is bent out of parallelism with the side of the frame A, as seen in Fig. 884. Now when a reciprocating rectilinear movement in a longitudinal direction is imparted to the slide-bar *v*, and plates S S, the pressure of the plates on the slides of the grooves of the pulleys *r r*, &c., will cause the various series of cutters during their revolutions to move back and forward laterally.



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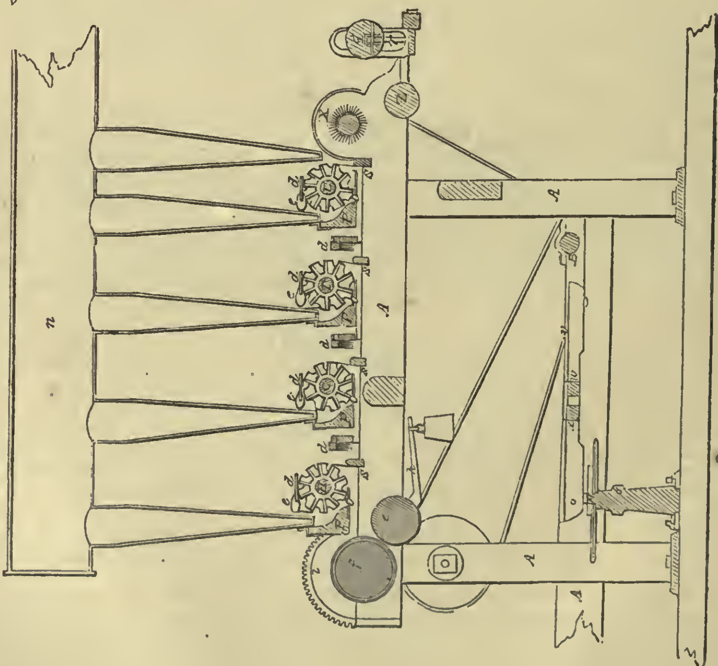

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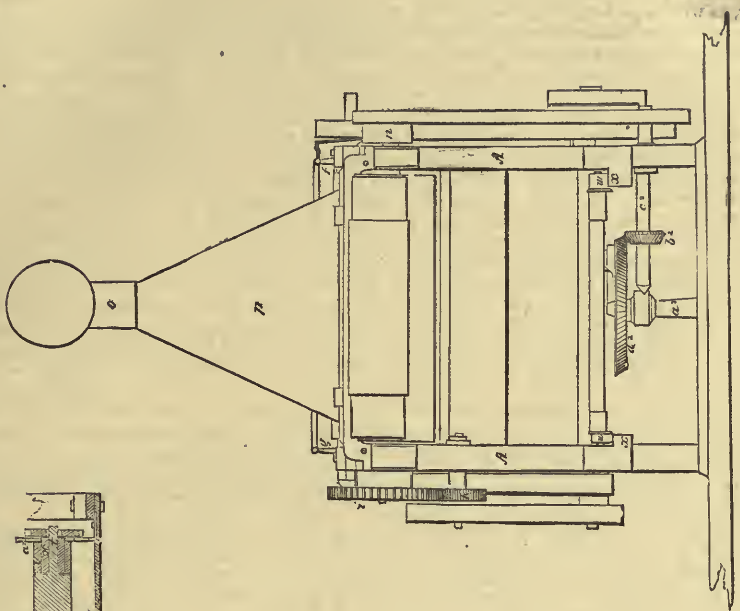

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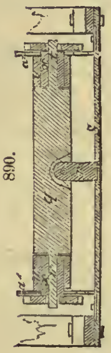

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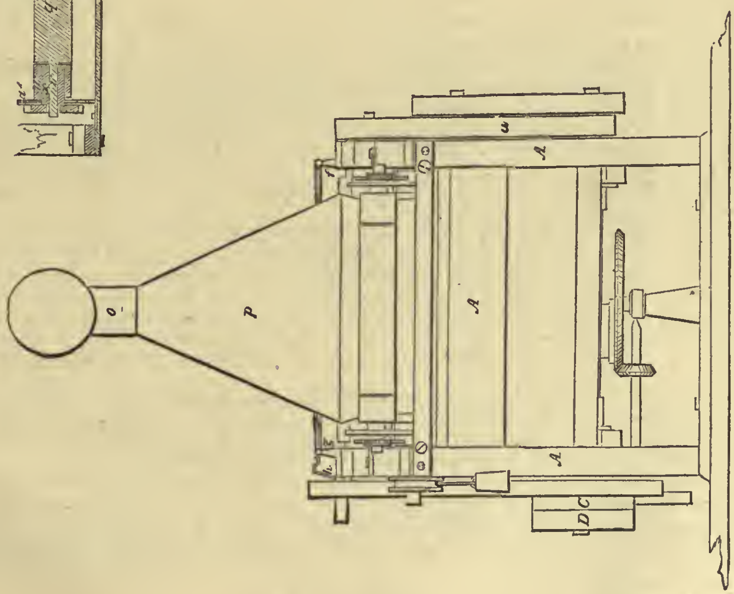

Two straight bars d^2 e^2 are arranged at the front end of, and transversely across the machine, and parallel to one another; one of them, viz. d^2, being fixed firmly in position while the other is made adjustable, or has adjusting-screws or other proper contrivances applied to it for the purpose of regulating its distance from the other bar.

The cloth is passed and moves between these bars, they being adjusted at such a small distance asunder, as will be just sufficient to allow the cloth to pass between them, while no knot or picker-wires or other extraneous substances which would be likely to injure the cutters, present themselves in the cloth.

When such matters exist on the cloth, and are carried in contact with the bars, they will either be removed by the draft on the cloth, or they will stop the motion of the cloth until they can be removed by an attendant.

The next and last portion of the machine to be described is the folding apparatus, which consists of a platform V, supported on two rails X X, by four or any other suitable number of wheels W W. The said platform or carriage should have a reciprocating rectilinear motion imparted to it in a longitudinal direction by suitable mechanism. That employed is as follows:

The carriage has a long plate of metal W secured transversely to its under side; through the plate a long slot X is cut, into which one end of a crank J is inserted, the crank being made to project from the top of a vertical shaft z, which turns in proper bearings of a post or standard a^3, supported on the floor on which the machine rests. On the shaft is a bevelled geer a^2, which engages with a bevelled pinion b^2, which is fixed on a horizontal shaft c^2, which has a pulley d^2 secured to its outer end around this pulley, and a pulley e^2 fixed on the shaft of the upper draw-roller to the carriage V, by said pulleys e^2, d^2, belt f^2, shaft c^2, geers b^2, a^2, and crank y and slot x acting together. The constant fore and back movements of the carriage causes the cloth, as it passes from between the draw-rollers, to be laid on it in regular folds. The manner in which the cloth is passed through the mechanism is seen in b 3 at Fig. 887.

It has been found from experience that the cloth is much better sheared when subject to the action of several series of rotating helical cutters, arranged and operating together as above, than it is when successively subjected to the action of one revolving series of such cutters.

The process of shearing, besides being performed much quicker by two or more series of rotary cutters and their adjuncts, as above specified, is more easily performed, and with less liability of injury to the texture or thread of the cloth.

By reference to the drawing, it will be seen that the position of the top edge of each of the ledges S, with regard to the bottom of the cutters or cutting-blade O, is such that the cloth, after passing over the top of said ledge, is by the ledge borne up against the under side or edge of the blade O, and so that the fur or nap which is to be removed is carried against the edge of the plate, and is cut off by the action of the revolving cutters. Consequently, should there be any knots, motes, or foreign substances projecting from the upper surface of the cloth, they will be removed by the upper surface and blade, and without injury to the cloth.

If the cloth passed directly over a ledge or rest placed under the cutters, as in machines for shearing broadcloths, cassimeres, &c., or thick and long-napped cloths of like character, it would be constantly liable to be cut into strips or otherwise injured.

By doing away with the rest, the cloth has the opportunity of falling, moving, or springing away from the blade when any very large knot or extraneous substance is presented to it and the cutters. The manner in which the cloth is borne against the under surface of each of the blades O, viz. by means of a ledge or rule S, or any equivalent in rear of each blade, we may dispense with the swing-bar which is used in the machine of Courlier to bring the cloth up to the blade, it being subject to the same objections as in the rest.

The machine of Courlier is described at page 8 of Traité Théorique et Pratique de l'impression des Tissus, par J. Persoz, tome deuxieme, Paris, 1846.

Mr. Whipple claims for his invention the manner of supporting the cloth during the performance of the cutting operation, viz. by the under side of the blade O of each of the series of cutters in combination with two ledges S S, or other mechanical equivalents whose upper edges shall be arranged in a plane with or a little above the said blade; the same enabling him not only to dispense with a rest such as in common shearing machines, but with the swing-bar used in the machine of Courlier.

He also claims the combination of two or more series of helical cutters E F G H, blades O O, &c., guide-rules S S, &c., and drawing-rollers as arranged, and operating together substantially as above specified.

Mr. Whipple also claims the apparatus by which the cloth is received at the front end of the machine, and caused to pass centrally into it or towards the cutters. Said apparatus being a combination of a rocking-bar, two pulleys, and two great pinions and racks or any mechanical substitute, the whole being arranged and made to operate together substantially as described.

Mr. Whipple further claims in the machine's combinations with the shearing machinery, the apparatus arranged over it for the purpose of removing the lint by upward currents of air as described; and the reciprocating carriage or moving platform for folding the cloth, in combination with the shearing machinery, the same being arranged and made to operate substantially as above explained; and the set of parallel bars d^2, e^2, as combined with and applied to the shearing mechanism in manner and for the purpose before described.

COAL. Charcoal will be found treated of in the article Iron.

* *Brown Coal* includes all that coal which does not form coke, and is younger, or of a more recent formation than bituminous coal or anthracite. As good fuel can be had abundantly, at reasonable, and even low prices all over the United States, there is no inducement to use this inferior mineral. All of it, which is either found in bogs, in alluvium, or in tertiary rock, is generally very impure, brittle and damp,

* Overmann's Metallurgy.

and with very few exceptions, perfectly useless in its raw state for any of the operations we have under consideration.

Bituminous Coal. Under this class we range all that mineral coal which forms coke; that is, it swells up on being exposed to heat, burns with a bright flame, blazes, and, after the flame disappears, there remains a spongy, porous mass—coke,—which burns without flame like charcoal. We also range under this class of coal the Nova Scotia coal,—the Frostburg coal of Maryland,—Richmond, Virginia, coal,—some North Carolina coal,—the coal of all the western fields belonging to the Mississippi valley,—the coal in Oregon and in California. There are, indeed, coal beds in these localities which are closely allied to either anthracite or brown coal, but we confine our classification to that kind which alters its form on being exposed to heat. The only points which claim our attention, are the chemical composition and the form of the coal.

In its composition we find chiefly carbon, oxygen, hydrogen, nitrogen, sulphur, and ashes, with a little water, which has been absorbed by the crevices. The following table shows the comparative composition of various sorts of mineral fuel.

Table showing the Composition of

	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ashes.
Turf	58·09	5·93	31·37	4·61
Brown coal	71·71	4·85	21·67	1·77
Hard bituminous coal	82·92	6·49	10·86	0·13
Cannel coal	83·75	5 66	8·04	2·55
Coking or backing coal	87·95	5·24	5·41	1·40
Anthracite	91·98	3·92	3 16	0 94

Quantity of Heat. The most important point, and one which has a direct bearing upon the value of coal, is the quantity of heat, which it can evolve in combustion. If we assume that the quantity of ashes is equal in the four substances mentioned below; that is, 5 per cent. in each, and suppose further, that pine charcoal furnishes 100 parts of heat,—the following table shows the quantity of heat which must be liberated in their perfect combustion.

Kind of coal.	Carbon.	Hydrogen.	Water.	Quantity of heat.
Brown coal	69	3	23	78
Coking coal	75	4	16	87
do	78	4	13	90
Anthracite	85	3	7	94
Pure Carbon	100	–	–	100

Quality of Heat.—The degree of heat which may be produced by coal of the above composition, on the supposition that pure carbon produces 4420°, is, in the first 3890°; in the second 3945°; in the third 3999°; and in the fourth 4142°. These results imply, of course, perfect combustion; that is—neither too much, nor too little oxygen is present. But this is practically almost an impossibility; therefore, these degrees of heat never can be realized, although the quantity may be.

If one ton of pure carbon is considered to be worth one dollar, the same weight of anthracite is worth 94 cents, that of soft, or bituminous coal, from 85 to 90 cents, and that of brown coal only 78 cents. In the valuation of coal we must consider the quantity of ashes as well as the quantity of water. The loss of heat occasioned by water does not depend merely upon the quantity; it is occasioned also by the conversion of it into steam; whereas the loss of heat from ashes is in direct proportion to their quantity, although not, perhaps, in all cases. The ashes of mineral coal consist generally of silex, clay, gypsum, iron pyrites, oxide of iron, lime, magnesia, and often chlorine and iodine.

Anthracite. This is the most important of all the class of mineral fuel, for metallurgical operations in this country, although not in other parts of the world. Pennsylvania anthracite is not only abundantly distributed in the eastern part of that State, but its great purity, and solid form, adapt it particularly to the use of the smelter and operator in metals. The chemical composition of anthracite is similar to charcoal, from which it differs chiefly in its form, being very hard and compact, and in the greater quantity of ashes which it contains. It is, like charcoal, unaltered in form after exposure to the strongest heat; even after passing through a blast furnace, it has equally as sharp edges, and is in form exactly as it was before. The following table presents the composition of some of the anthracite of Pennsylvania.

	Composition.			
Locality.	Carbon.	Volatile matter.	Ashes.	Specific gravity.
Lehigh coal, Summit mines,	88·50	7·50	4·00	——
Schuylkill coal, Tamaqua mines,	92·07	5 03	2 90	1.57
Pottsville,	94·10	1·40	4·50	1·50
Pinegrove,	79·57	7·15	3·28	1·54
Wilkesbarre, Luzerne Co.	88·90	7·68	3·49	1 40
Carbondale, " "	90·23	7·07	2 70	1·40

The ultimate analysis of anthracite shows it to be composed of 90·45 carbon, 2·43 hydrogen, 2·45 oxygen, some nitrogen, and 4·67 ashes. Another specimen of Pennsylvania anthracite was composed of

94·1 carbon, 2·39 hydrogen, 87 nitrogen. 1·33 oxygen, and 1·3 ashes. The ashes generally consist, like those of bituminous coal, of silex, alumina, oxide of iron, and chlorides, which generally evaporate and condense on cold objects in the form of while films. Some of this coal contains considerable quantities of sulphur, which is chiefly found in the fine parts and slack, in consequence of the coal having been broken into lumps of uniform size before use, and, because the sulphureous parts are the most brittle and slaty.

Anthracite is not so inflammable as either dry wood or bituminous coal, but it may be made to burn quite as vividly as either, by exposing it to a strong draught, or in a large mass, to the action of air. This absence of flame in this coal, arises chiefly from the lack of solid, heated particles in the gases, and as transparent hot gas does not radiate heat, no matter what may be its temperature, it has been found that the anthracite flame does not heat the hearth of a reverberatory so well and so quick, as bituminous coal or flaming wood. This evil can be remedied by applying a blast under the grate of a furnace. Thus fine particles of coal are carried over by the hot gases, and the flame so formed radiates heat as well as that of any other fuel. It is manifest, that the pressure of blast, or the force of the current of air, which is to tear loose these particles of coal, must be in proportion to the refractory nature of the coal. If the draft is too strrong these particles will be too large, and therefore be deposited on the hearth where the current has not sufficient strength to keep them suspended; their effect is thus lost. If the particles are extremely small and the furnaces so constructed as to retain a lively current, their subsidence is prevented. A large grate is, in this instance, more suitable to form a good substantial flame than a small one, for a gentle draught in it will produce only small particles, while a strong blast tears off large ones which are of little use. Sometimes the ashes which are formed by anthracite and deposited in the flues, or on the hearth, are a cause of objection. This evil, if it cannot be entirely obviated, can at least be greatly modified by increasing the surface of the grate.

COCKS. See Faucets.

* Coking of Coal. An essential condition in forming coke is that the coal, on being heated, swells and changes into irregular spongy masses, which adhere intimately together. This operation is designed to expel sulphur and hydrogen, and form a coal which is not altered by heat. The sulphur cannot be entirely separated from coke, or from carbon, no matter how high the heat may be; neither can all the hydrogen be removed from carbon by simply heating the compound. If oxygen is admitted to these combinations, both sulphur and hydrogen may be almost entirely expelled, that is, provided the oxygen is not introduced under too high or too low a heat.

Coking in the open air. When coal abounds in sulphur, as well as bitumen and water, the best mode of coking it is in rows or clamps; that is, in a long pit or heap, a section of which is represented in Fig. 891. The length of such a heap may be from 20 to 100 feet, or, in fact, it may have any length;

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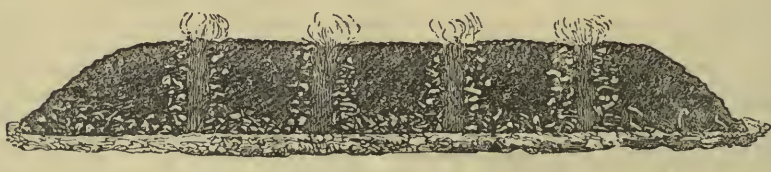
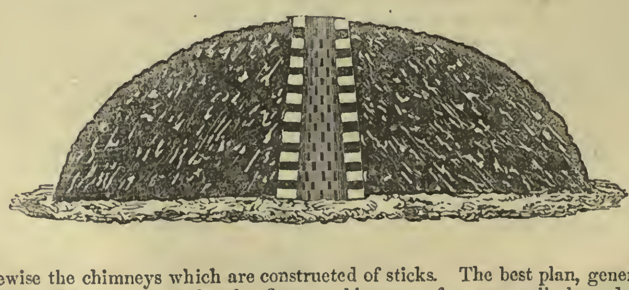


but its width must not exceed from 6 to 12 feet. If the coal is very impure the heaps must be narrow, but if it is hard and pure, it may be charred in wide rows.

In a row, such as is represented above, the coarse coal forms the skeleton of the heap inside, and at distances of 8 or 12 feet, a kind of chimney is constructed with it. If coal coarse enough for the purpose cannot be had, a flue is constructed of loose fire-brick on the floor, over the whole length; this forms an air channel. Chimneys are erected of bricks in the proper places, as shown in Fig. 892. Sometimes, especially where wood is cheap, a longitudinal channel, and also cross channels are formed

892.



with it, and likewise the chimneys which are constructed of sticks. The best plan, generally, is to form air-channels through the bottom and also the flues or chimneys, of coarse well-charred coke; these do not swell; they hold good fire, and cause no loss—for what is burned in one kind of coal is saved in the other; besides, this method furnishes the best coke. One of these long heaps of coal is from 3 to 5 feet high, according to the kind of coal; it consists of coarse coal, covered by small coal and, at last, by slack.

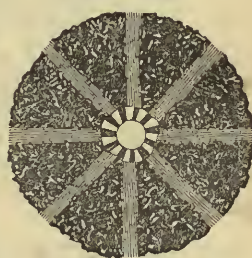
* Overmann's Metallurgy

Fire of wood or burning coke is applied to the foot of the pile, at such distances as will secure a uniform distribution of it and in the very vicinity of the flues which lead to the chimneys, as these are most suitable to conduct it into the interior. One end of a pile may be kindled, burn and even be finished while the other end is building; thus coke may be formed in a short time. The collier must aim to conduct the fire into the interior as quickly as possible, and heat from within outwards; in fact this operation must be done on the same principle as in charring wood. But, since stone coal is less valuable than wood, and as a higher heat is required to drive off impurities, and also more fresh air, and moisture to expel sulphur; the burning coal must necessarily be worked more openly, and under a more brisk heat, than wood. When the fire is well spread through the interior of the pile, and its progress is safe, the sides of the row are covered by coke-dust, but the base and top are kept free, so as to admit of a lively combustion and a strong heat. In fact, a large quantity of air, and if possible damp air, is required at this time to pass through the coal, if good coke is expected to be made. After the lapse of 24 hours, more or less, the heat is well distributed and the flames on the comb of the pile disappear, and hot invisible gases only escape. The pile is now closely covered with coke-dust, and left to cool: this requires another 24 hours, so that in two days' time, the coke is burned and ready to be drawn.

Coarse coal fresh from the mines is best suited for this mode of coking. It should be adopted in all cases where the coal is impure, and a good article is required; for, by no other method than this, can so good coke be obtained. Other modes will furnish more coke from the same amount of coal; but good coal is required to make coke strong and pure, such as is suitable for iron smelt furnaces. The foregoing method cannot be used when the coal is fine, that is, when it consists mostly of slack coal, because such coal is too close and does not admit of the passage of air sufficiently to form good coke. It is often charred by mixing it with small wood, chips, or bushes bound in faggots, but this is expensive, and where wood is scarce cannot be resorted to. The coal then is charred in large heaps, or pits, like wood. Such a pit may be from 20 to 25 feet in diameter, and from 3 to 8 feet high, according to the quality of the coal.

A strong chimney of fire-brick is erected in the centre, affording many flues which lead to the interior of the mass. It is built very open and without mortar. On the floor there should be a series of channels in a radial direction, as shown in Fig. 893. These are formed of coarse coal, or, which is better still, of large lumps of coke, so as to be always open. Flues of fire-brick do answer the purpose, but are not so favorable to the quality of coke as coke channels. These and the floor are covered with the coarsest coal which the mine affords, and when it is exhausted fine coal is spread over them to a height of 2 feet or more, according to its quality. Fire is now applied to the flues at the circumference, and urged to a uniform and lively state. A dense smoke issues at first from the top of the chimney. This soon ceases, and a white flame of carburetted hydrogen takes its place. Within two or three hours, the smoke and some fire appears at or near the top of the coal, which indicates that the fire is well spread in the interior. The remainder of fresh small coal is now gradually thrown on, but in such a manner that the heat is not checked. Some smoke ought to issue from the coal at all times, besides the flame from the chimney. Coal is therefore thrown on gradually, to the height which may be desired, so that the heat follows to the top as the mass increases. When all the coal is put on, the fire is permitted to break through, and show its white flames at the surface. Those places which are hottest, and where the white flame ceases, are covered by coke-dust; meantime other places which do not work so lively, or are behind, are urged by running an iron bar into the heap so as to make draught-holes, thus securing a more lively combustion. When all the coal is thus heated uniformly to the top, the heap is covered by coke-dust. At the foot the air is still admitted for some hours, so as to heat the heap thoroughly. When the inflammable gas ceases to appear at the chimney, the cover of dust is extended to the foot of the heap, but the chimney is still kept open for some time. Finally it is closed at the top by a slab or a cast-iron plate. The dust-cover when a white heat is perceptible below is well secured by throwing dust around it. All the vents on the surface are now covered closely, and the earth increased so as to prevent all access of air to the interior. Three days, and often four or five, are required thus to char a heap of coal. This manner of proceeding applies to slack coal. There is no advantage in charring coarse coal in heaps: it is coked cheaper and better in rows.

Fig. 393



When the coal abounds in sulphur, the heap is opened in places before it is cool, by means of a crowbar, and water is thrown upon the coke although still red hot. Thus a large quantity of sulphur may be expelled, which will be manifest by a strong smell of sulphuretted hydrogen. The effects of this mode of driving off sulphur on the other qualities of the coke are somewhat doubtful; for it invariably has a tendency to weaken the coke and cause it to be spongy and friable. It requires, therefore, a strong coke, which has been produced by a strong heat, to resist the weakening influence of water.

The quantity of coke produced from coal varies according to the quality of the coal, and the mode of operation. It is not often that more than 50 to 55 per cent. by weight is obtained in rows; although coal which does not contain much hydrogen or water, may reach 60 and even 65 per cent. The yield in heaps is somewhat better, and can be brought, by close attention, to 60 or 70 per cent. The coke from coal generally amounts to more by measurement than the quantity of coal that is burned; this varies from 100 to 125 bushels of coke from 100 bushels of coal; it is not often less than 110 bushels.

The coke yard ought to be level throughout, and dug, or ploughed over, so as to remove all stones and damp places within two feet of the surface, and uniformly covered by a loose and light soil. This yard is surrounded by a ditch, into which rain and spring water flows, and which ought constantly to contain some water, which may be at hand when needed, and also moisten the ground. The object of

this is to impart by these means a certain degree of dampness, but not too much, to the whole yard. In the course of the operation the yard is covered by coke dust, which, when mixed with soil, is very suitable to retain moisture; but the presence of water around the yard, enables us always to obtain damp dust by digging. A damp coke yard possesses great advantages for driving off sulphur from coal. This substance adheres tenaciously to carbon, and no degree of heat can expel it; not even with the assistance of fresh air. The best method, therefore, to desulphuret coal is found to consist in highly heated steam. Consequently, if coal is heated on a damp ground, steam is generated, which, in passing through the hot coal, is decomposed and carries off sulphur. If the heat is too high, or too low, these means ar as ineffectual as any others; it is difficult to hit the exact point. If moisture is always present it wil act at the proper time. When the coal is at the highest heat, no vapors will issue; the ground is dry, and none are needed.

The principles involved in making coke are exactly the same as in charring wood, with the exception that coke is less combustible than charcoal and less care and attention is required to obtain good results. The fire should always work from the interior to the exterior, and the more this is attended to, the better will be the yield. When coal is very impure, or fine, it is necessary to work with less cover, in order to make quality, but this is always accompanied by a loss. Sometimes the flues are formed by erecting poles, of 10 or 12 inches in diameter, after the coal is thrown around them, and before the fire is applied they are withdrawn. This mode of forming flues is only applicable where the coal is coarse and does not bake too much. But in such cases no flues at all are needed; the coarse coal, when piled openly, forms sufficient spaces for draught. When coal is very bituminous, and swells considerably, it must be set with large spaces, and good safe flues; and, in order to insure good work, it is coked without any cover of coke dust.

Coking in ovens. This method is resorted to, in order to obtain more coke, work slack coal and save labor; but coke made in ovens is never so free from sulphur as that charred in the open air.

The varieties of form in coke ovens are innumerable. In Fig. 894, is represented a vertical section of a coke oven such as is mostly in use in the western States, and other regions where coke is made. It is generally built against a hill-side, and is accessible, at the top where the aperture is, by a road, so that the wagons may deposit their loads of coal most conveniently to it. The form of the interior of the oven resembles that of a common baker's oven, only it is round as represented in the plan, Fig. 895. The hearth is from 10 to 12 feet in diameter, and has a door 2 feet in width on one side. The arch is in its centre or highest point, about 3½ or 4 feet above the bottom, and about 18 inches or 2 feet in its span. The opening in its centre is from 20 to 24 inches in diameter. The entire hearth, both the bottom and arch, is constructed of fire-brick; the rough walls around these may be either of common brick, or rough or dressed stones. Two or more ovens are generally built together, as shown in Fig. 896. This arrangement saves labor, because there is always more than one hand required; and two or three hands may quite as well tend as many ovens.

Fig. 894.

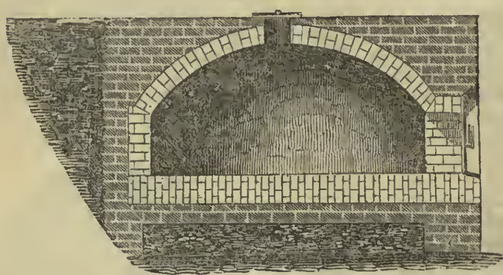
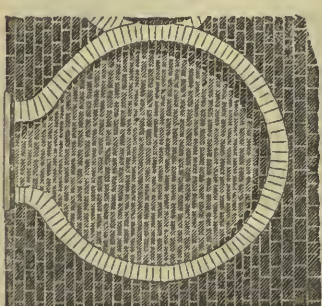


Fig. 895.



The manner of using these ovens is extremely simple. If one is cold, which is always the case when new, or on Monday mornings, a quantity of wood is first spread over the hearth, and kindled; meantime some lump coal is added. This fire is then continued briskly, until the arch and sides are red hot. The ashes are either removed, or drawn towards the door by means of a long hook, or left where they are, in case no harm is done to the coke. When the oven is hot, the coal is thrown in at the top, and spread uniformly over the hearth, by another hand at the side door. The height of coal upon the bottom, depends on the kind of coke which is to be made; if it is to be close and heavy, the stratum is from 16 to 20 inches thick; and only 12 or 14 inches if it is to be pure, in which case the coke is more spongy. When all the coal, which varies from two to three tons at a time, is charged, the door is shut, either by means of a cast-iron plate, or by fire-brick. A few small apertures, however, are left open for the access of a little air, which are stopped as soon as the heat inside is strong enough to drive off the volatile matter. From the aperture in the centre of the roof, a thick dense smoke at first issues which is soon supplanted by a bright flame. It is not good to increase the heat too rapidly by throwing in the coal too fast; there is no need of haste in charging, for nothing is gained by it; on the contrary, loss may ensue. When the coke is thoroughly heated, which takes about 15 or 16 hours, the flame ceases at the top, and all the openings in the door and at the top are closed; still a few small crevices may be open which admit a little air. This causes the heat to become intense, and then the coke draws together, and forms a more close and compact body. This last heat, which requires about two hours, settles the coke. All crevices and joints are then carefully closed, and the oven left for some hours to cool. One heat requires from 20 to 22

hours, and when all things work well, an oven must be heated and discharged in 24 hours. This, however, depends very much on the quantity of coal which is charged. A high stratum requires a disproportionally longer time for charring than a low one; when, therefore, the object is to make much coke and work cheap, it is not advisable to put too much coal into the oven.

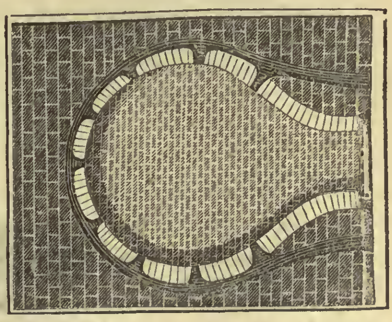
896.

The discharging or drawing of the coke ought to be done while the oven is red hot. It must be done quickly, so as not to lose too much by combustion, and also not to cool the oven, in order that fresh coal may inflame at once when it is charged. The door is opened, but the cast-iron plate which shuts the top is not removed. As the coke forms a solid cake, which is often very strong, a long heavy iron bar is driven in at the bottom, by which the cake is broken, so as to form pieces of a limited size. The coke, when thus drawn from the furnace, is dropped on the ground, and the hot mass sprinkled with water by means of a watering pot and syringe. This damping of the hot coke, cools it for removal, and in the mean time causes some of the sulphur to evaporate. When the hot coke is removed, fresh coal is immediately thrown into the oven, provided it is not too hot; for an unnecessary loss of coke is the consequence of a decomposition of the coal too rapidly.

Ovens do not furnish the cheapest coke, and of course not the best kind. Their superiority over coking in an open yard, consists in working slag coal with greater facility than it can be done in the yard. The yield in an oven, in weight and in measure, may be pushed very high, by applying a low heat in coking; 80 per cent. and even 85 per cent. in weight may be obtained, by 150 or 160 bushels, in measure. The coke thus obtained is not strong and heavy, but always spongy; it burns with flame, and is not suitable for smelting, notwithstanding however good it may be, for use in locomotives. Good coke, even if made in ovens, must be silver-gray, crystallized in columns, and shingle like good well-charred charcoal. The coke ovens near and around Pittsburg, Penn., furnish a first-rate article from slack coal. An oven will not furnish much more good coke from a certain weight of coal, than the heap or row in the yard. The average return of good coke formed by a high degree of heat, is from 55 to 65 per cent. in weight, and 100 to 120 per cent in measure.

A certain quantity of air, and if possible moisture, ought to pass through hot coke, as we have shown, in order to purify it. This does not take place in the ovens above described. A little air passes in at the door, but that of course cannot reach the mass of coke. Experiments have been made to introduce air by perforating the bottom; but they have been found to be of little avail, because the coke soon becomes so close as not to admit of its passage. The most successful method of producing good coke in a large quantity, and also for accelerating the work, is the constructing of a channel around the inner wall of the oven, a horizontal section of which is shown in fig. 897.. The air is drawn in at both sides of the door through this channel, which is about 6 inches wide, between the rough-wall and the lining of the oven, and conducted by small apertures into the oven; there may be nine or ten of such flues or tuyeres 2 or 2½ inches wide in the circumference. These air-holes must be above the stratum of coal. A couple of bricks will serve to close the entrances to the main channel when necessary. The operation of this air channel is plain. Whenever it is open, the air furnished by it will cause the gases which escape from the coal to burn, and heat the arch and the top of the coal. By increasing the heat in the oven, it consequently accelerates the operation, and causes a stronger coke to be made. This channel must be used with discretion and judgment, for if it is either opened too soon on the fresh coal, or suffered to remain open too long on the hot coke, it causes waste.

Fig. 897



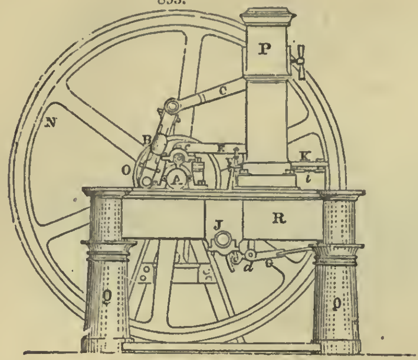
For the formation of good coke, the coal should not be higher than 12 inches, and the highest part of the oven not more than 3½ feet from the bottom. There is little harm done in having the arch only 3 feet high in the centre, and 18 inches around the circumference.

COG-WHEELS. See Geering.

COINING MACHINE. Figs. 893 to 903, are elevations, sections and details of a machine for stamping money, invented by M. Thonnelier, and combines economy with perfection of workmanship, durability of the machine, and safety to the operatives.

The moving power applied to a winch, or rather a steam power, turns a fly-wheel which governs it, and sums up all its powers at the moment the piece is stamped. To the axle of this fly-wheel a spira

893.



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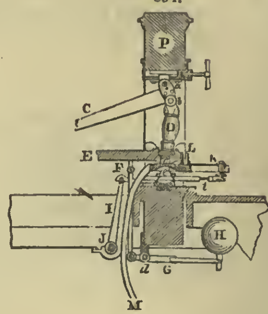

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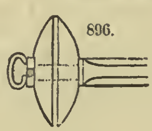

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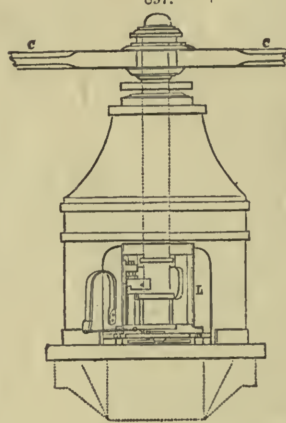

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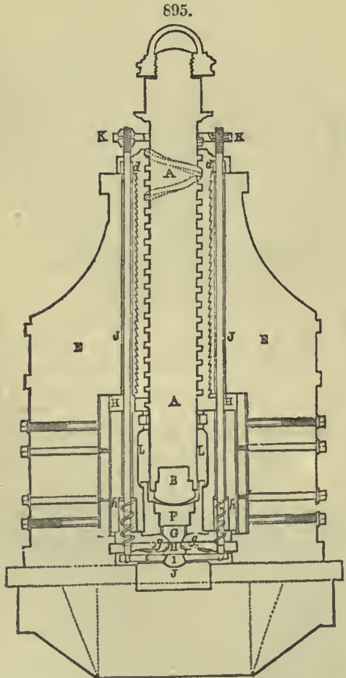

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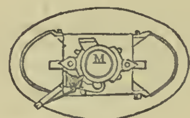


899.

Fig. 893, lateral elevation of the machine.

A, principal axle turned by a winch or moving power.

B, connecting-rod giving to the lever C the movement of the winch adapted to the axle A.

C, lever whose centre of movement is at *a*, in the interior of the cast-iron *f* P; it makes the second cylinder *b* revolve the arc of a circle.

D, a force column of steel. It moves at its lower part, in the box E. Its upper portion is joined to the lever by the intervention of the steel cylinder *b*.

E, a sliding-case leaning against *c*. It is maintained by a double beam F; a lever G, fork-shaped, bearing the two balls H, hold the case against D. The supporter and the lever of the case revolve round an axle in *d*.

I, an iron lever receiving from another lever concealed by the machine, an impulsion transmitted by the eccentric fixed to the plate O of the fly-wheel N; these two levers are fixed to the axle J, which is the means of placing the metal, and of drawing it off when stamped.

i, a lath communicating with the lever I, and destined to raise the point *c* on a level with the side-plate of the ferrule.

e', inferior stamp.

K, placing hand. It has at its extremity an instrument to take the coin off, should it be attached to the superior.

This portion of the machine comprises several pieces; viz. the side-plates of the ferrule; the ferrule, &c.

L, a tube which receives the metal about to be coined.

M, a passage through which the coin passes to fall into the basket.

N, fly-wheel.

O, a cast-iron plate attached to the axle of the fly-wheel.

P, cast-iron case of the machine.

Q Q, four cast-iron columns giving support to the frame of the machine R, likewise made of cast-iron.

curve is adapted to direct the movements of a connecting-rod, which transmits to the moving parts the mechanism of placing and taking off the metal between the stamps, and withdrawing it from the ferrule after the money is stamped.

The power accumulated by the fly-wheel, is transmitted through its axle to a winch, which acts upon two arms joined to each other by a hinge at their extremities, and forming a very obtuse angle, which can be opened or closed a little. When this angle is opened, the two other extremities of the arms or levers become more distant, and as the superior meets a buttress, it is the inferior one which moves; it is properly a funicular lever or mechanical knee. Thus the lower part of the inferior lever is drawn towards a resisting plane, when the angle of the two arms widens, but on the contrary it is carried away from the plane when the angle closes; the movements are produced by the connecting-rod and the winch fixed to the fly-wheel.

The two stamps are placed, the one at the moveable end of the lever, above the metal to be coined; the other is situated beneath, the two planes being parallel.

The pieces to be coined are piled up in an iron cylindrical vessel, and at every turn of the fly-wheel, the nether piece is taken away, and pushed under the press, being contained within a ferrule which limits its circular diameter. When the lever rises, the coin spontaneously leaves the ferrule.

Cylinders.—The principle of this press consists in two cylinders having their axes parallel, and turning in opposite directions.

These cylinders have on their outer surface engraved matrices, smooth and fluted ferrules, as well as ferrules with inscriptions.

Fig. 900 presents a transversal section of the machine perpendicular to the axis of the cylinders.

Fig. 901 is a vertical section made through this axis.

The cylinder A receives the movement of the moving power; its axle has length enough out of the case to have cogs B engaged into the pinion B′, on the axle C. This axle has a fly-wheel C′, and can be set to work by any moving power through the pulleys D D′.

The second cylinder A′ is constructed almost like the first, and of equal diameter, having the same number of matrices.

Two wheels E E′ are connected with one of the extremities of the cylinders in order that they may receive motion.

In the swollen centre of the second cylinder A′, and on its surface, there are excavations to receive the matrices *a*, Fig. 902; they are cylindrical; metallic disks *e* support the matrices, whose distance from the centre, or from the circumference of the cylinder, is thus governed. Buttresses *b* placed on each side of the matrices are inserted into the cylinders, to push the matrices outwards. This forces the iron out; which, when effected, the buttresses are sent back to their original position by the spring *d*. At the central part of the outer surface of the cylinder A, grooves are made to receive the ferrule matrices *a*′, the form of which is hemispherical, Fig. 903, so that they can oscillate through the rotary motion of the cylinders. The plane surface which terminates each matrice, and which is engraved, passes through the centre of the sphere, but the outer circumference of this surface should be somewhat eccentric, to the surface of the sphere.

Pillows can be placed within the groove under the matrices; they are of steel, and can be regulated by a screw. The matrices are by this means secured from oscillations.

Steel springs *e*, Fig. 900, act upon the sloped edges of the ferrule matrices, to forrce back these last to the place they should occupy, as soon as they are no more opposite the matrices *a*.

A tube F, containing the pieces about to be coined, furnishes them to the matrices. The circumference of the second cylinder A is surrounded with steel plates *f*, which have at their centre a cylindrical hole of equal diameter with the matrices *a*; these plates serve to stamp the circumference of the coin. When the cylinders are placed as represented in Fig. 900, the lowest piece in the tube F is in contact with the surface of the plate; as soon as the matrice comes to the orifice of the tube, the piece falls into the vacuum formed by the plate, and comes in contact with the engraved surface of the matrice. The cylinder continuing its rotation brings the metal within reach of the ferrule matrice, and the coin is stamped on both sides at once.

It is then pushed out of the matrice by *b*, assisted by the scraper *g*, which has a counterpoise.

The turning-pieces of the cylinders are received in pillows which allow them no lengthwise displacement; and in order that the matrices may be retained in the same plane, perpendicular to the axis of the cylinders, these are exactly clamped between the two cheek-pieces of the cases which contain their pillows. Wedges pressed by screws *h*, hold the pillows firmly fixed. The coins, as they fall, receive no shock, and are received in a box enclosed within J, the frame-work of the machine.

Such a machine coins more than 100 pieces in a minute, or 60,000 pieces in a day of 10 hours' continual labor. The moving power required is but slight. This press performs its functions without noise, and is not liable to be put out of order; its construction is simple, and it occupies little room. The workman who attends it is perfectly safe during his labor.

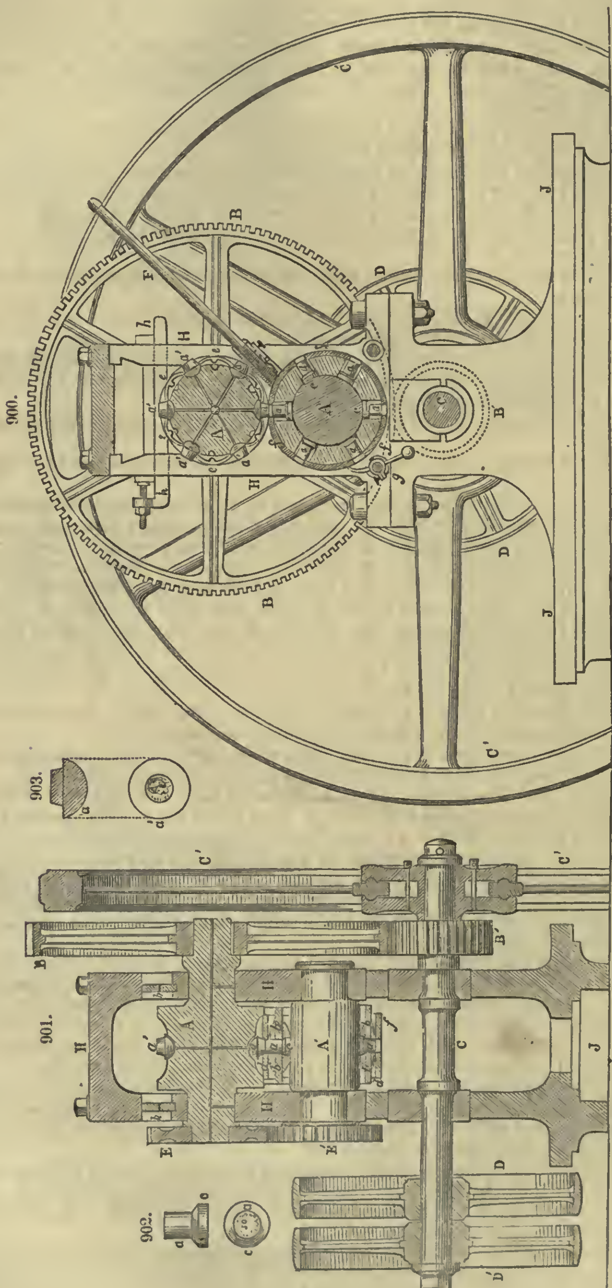
Should any accident or obstacle occur, the machine is so arranged that it stops spontaneously; the fly-wheel C′ is maintained on the axle by a species of break, Fig. 901, which allows it to turn back without turning the axle, when a greater resistance than usual is experienced by the matrices, so that the attendant is made aware of the accident.

New Method proposed by M. Béguin to stamp Money, Medals, and Jewelry.—This consists in placing within the matrices a certain number of steel stamps. These matrices being piled one upon the other, are enclosed in a rectangular box, and made to pass between two cylinders. This pressing is performed rapidly, and many pieces are worked in a short while.

The stamps are placed within the matrices, and are of a slightly conical shape; in order that they may be retained at the same level, a strong plate covers the matrices. A thin plate is interposed between the two matrices, and is pierced with a number of holes equal to that of the stamps; its use

is to keep the pieces to be stamped in connection with the stamps; this plate is made of steel, having its surfaces even, and an equal thickness in all its points.

The system is carefully fixed into a rectangular frame, which is of iron, and holds the different parts so firmly fixed, that they are not deranged while between the rolling cylinders.

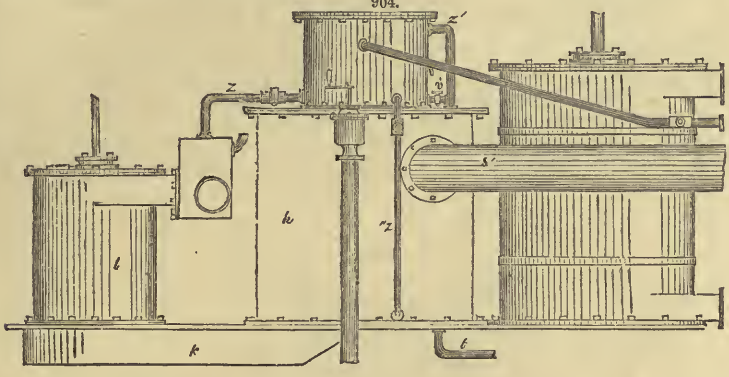


900. 901. 902. 903.

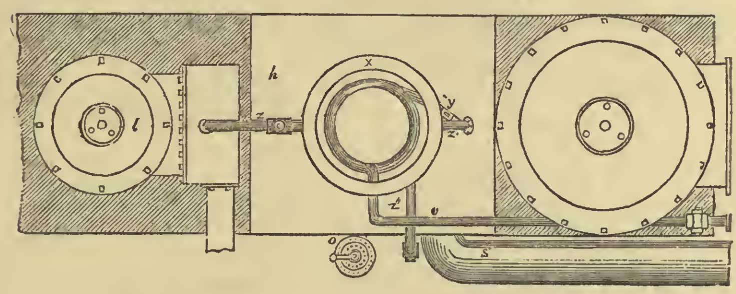
CONDENSER. The usual modes of condensing steam, where it is used as a motive power, are by allowing it to escape into the air; by injecting it into a vessel or vessels which are kept at a low temperature by immersion in cold water, or a current of air, the steam being cooled by contact with the

metal; and by injecting it into vessels in which it is brought in direct contact with a jet of water. In the first instance, the water resulting from the condensation of the steam is lost; in the second, it is retained in the vessel in which it is confined, unmixed with any other substance; in the third, it is retained, but is mixed with the water used for condensing it. Condensing engines are those which employ one or the other of the two last-described plans. In marine engines, or where salt or other impure water is employed for condensing the steam, this latter plan involves the loss of the fresh water resulting therefrom, in a manner well known, and consequently either the boilers must be supplied with bad water, or a supply of pure water must be specially provided. In most cases this cannot be accomplished, as it has been found impossible to carry a sufficient quantity to last for any great length of time.

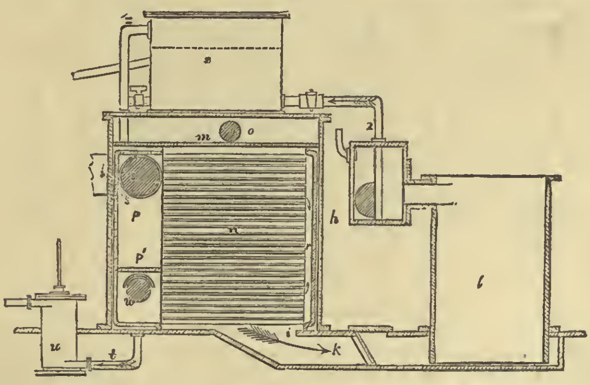
904.



905.



906.



This being the case, attention was early (in the history of the steam engine) given to perfecting the second mode named herein—viz.: the condensing of the steam by radiation in closed metallic vessels, kept submerged in water. In this plan the boilers are to be first filled with pure water; the steam being condensed back to water, is thus caught and returned to the boilers, to be used over and over again; the leakage and waste being supplied from reservoirs provided with an extra quantity, or by distillation. The steam being condensed in vacuo, the external surface of these vessels is thereby subjected to the pressure of the atmosphere, and also to the pressure of a column of water, proportioned to the depth at which they are immersed. In fig. 907 is a view of the usual mode of constructing this kind of condenser: a is a cluster of pipes, (that being the best form to resist pressure,) inserted in two flanges, b;

the ends of the pipes are covered at c by a cap, and at d by the channel in the bed-plate; e is a tank to hold the water for condensing, which flows in and out as indicated; f is the exhaust-pipe for conveying the steam to be condensed; g the air pump. The steam is thus condensed by coming in contact with the cold surface of the metal, the pump, g, maintaining the vacuity of the pipes by removing the water as fast as it accumulates in the channel d, and also any air or other gases Hence the external surfaces of the tubes are subjected to the pressure of the air, and also to that of the column of water in which they are immersed, as before named. This mode of condensing steam has these difficulties to contend with, and which have hitherto been found insuperable. The alternate heating and cooling of the metal pipes, consequent upon the periodical injections of the steam, causes a series of expansions and contractions to be continually going on. In addition to this, the great pressure upon them soon produces fractures in the various joints and seams, which at once destroys the whole operation, as the vacuum can no longer be maintained from the flowing in of the air, and also of the water, which is fatal to the whole operation.

Fig. 907

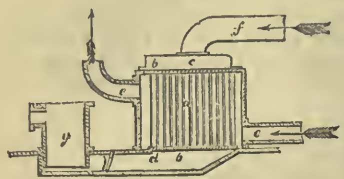
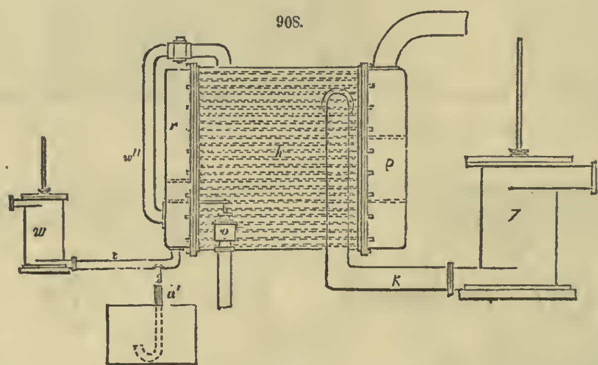


Fig. 904 is a side elevation; fig. 905 is a top view: fig. 906 is a longitudinal section of Pirsson's patent condenser. Figs. 908 and 909 are views showing variations in the construction of the same ap-

908.



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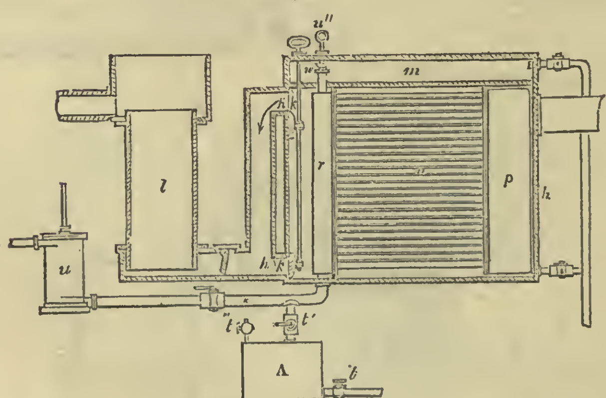


At the letter h, fig. 906, is represented a box or case composed of metal, and of sufficient strength to resist the pressure of the atmosphere, and is also to be made as perfectly air and water-tight as possible. In the under side of the box h, there is an opening i, through which a connection is made by a pipe or channel k, with an air-pump l, of common construction, as shown in section, fig. 906. At m is a perforated plate, on which the condensing water is received, and is for the purpose of dispersing it in a manner well known. A pipe and cock are attached for injecting the water for condensing the steam. Into the box thus constructed, is introduced a radiating condenser, that is to say, a vessel or apparatus in which steam is to be condensed by contact with cold metallic or like surfaces, which is made as follows:—At n, fig. 906, is seen a number of tubes arranged horizontally, their ends being fixed in plates or flanges of metal, having holes perforated to receive them; the ends of the tubes are covered by attaching caps, p and r to these plates, as shown in section, fig. 906. The tubes thus arranged, are in-

troduced within the box h, as shown. In the cap p there is an opening made at s to receive the end of the pipe which conveys the steam to be condensed, which pipe is seen at s'. The steam-pipe s' is bolted to the outside of the box h by a flange, the end passing through and made to enter the cap p, through the hole s as shown. The cap p is divided into two compartments by a partition p', the object of which is to cause the steam to traverse through two sections of pipes. More partitions may be introduced, or any other arrangement may be adopted to insure full and equal distribution of the steam to each pipe. At t is shown a pipe connected with the lower side of the cap p, which passes through the box h, having a tight joint where it comes out. This pipe terminates in a pump u, the use of which is to pump away the water resulting from the condensation of the steam, and which collects in the bottom of the pipes and caps. At w is an opening in the lower division of the cap p, which forms a passage from the pipes to the interior of the box; the use of which will be described more fully. This opening w, is to have a door or valve over it of common construction, which may be opened or closed by a handle from the outside of the box h, the handle working through a stuffing box in h. It is obvious that other forms may be substituted, as sheets of metal, coils of pipe, instead of tubes or pipes.

The operation of this part of the invention is as follows:—The engine being started in the usual manner, the exhaust steam flows through the pipe s', into the cap p, and thence into the cluster of pipes n; at the same time a jet of cold water is admitted through the injection cock o on the perforated plate m, from which it falls in a shower upon the pipes n, and thus, by a well-known law, at once condenses the steam—the water resulting being collected in the bottom of the pipes and caps—the large pump l removing the condensing water as fast as it accumulates from the box h, and maintaining the vacuum, —the smaller pump u removing the water resulting from the condensed steam. In like manner the condensing water is allowed to flow off as fast as discharged from the pump l, but the water taken from the pipes is retained for the feed to the boilers. The use of the aperture w, is for the purpose of maintaining an equal pressure on each side of the pipes, or rather to prevent them from being subjected to any pressure, either internal or external. This can be made apparent as follows:—Supposing the orifice w closed, and cold water admitted in quantity sufficient to condense a part of the steam only, it will be evident that the vacuum in the box h will be better than the vacuum in the pipes, and the difference will be as the volumes of uncondensed steam. Now if we open the door or valve over the aperture w, a portion of the steam in the pipes will at once rush through and extend itself throughout the box h until an equilibrium is produced. So long as the steam is fully condensed, and also the operation of the pumps l and u equal, then, of course, the radiating condenser n will be subjected to the same pressure, both external and internal; or rather, will not be subjected to any, even if the orifice w be kept closed. The use of the opening w, therefore, is to insure the preservation of the equilibrium in cases where the steam is not fully condensed, or where the pumps fail to work equally: the atmospheric pressure being sustained by the box h.

An apparatus for making up any deficiency in the supply of pure water which may arise from leaks and other means of waste. At x, figs. 904, 905, 906, is seen a tank, standing upon the top of the condensing box h (but may be put in any other convenient place). This tank must be air and water-tight, and also capable of sustaining the pressure of the atmosphere. At y, fig 905, a steam-pipe is attached, which may terminate on the inside in a coil or cluster of pipes, or other chamber for holding steam, as shown. The lower end of this coil terminates in a pipe, which passes out through the side of the tank at y', and empties into another pipe as shown. z is a pipe attached to the lower side of the tank x, the opposite end of which terminates in the "hot well" of the air pump l, or other reservoir containing a supply of the water to be evaporated; z' is a pipe attached to the upper side of the tank x; it is bent so as to pass down through the top of the box h, to which it is bolted by a flange, the end terminating so as to discharge into the cap p, of the inside condenser, as shown; z'' is a pipe attached to the tank x near its bottom, by one end, and by the other to the box h, so as to discharge into it. To put this apparatus in operation, the engine is first set in motion, and the condensation of the steam going on, the vacuum of the box h will be communicated through z' to the tank x, the interior of which will consequently be in vacuo. The cock to the pipe z being opened, water from the hot well of the pump l will flow into x by the pressure of the atmosphere; the tank is to be filled sufficiently to cover the coil of pipes, or as seen at the dotted lines. Next, steam is to be admitted through y, the cock y being kept closed (except when it is necessary to draw off the water which may collect from the condensation of steam in this place).

By this means the water in x will be vaporized, the vapor being drawn off as fast as it rises through the pipe z' into the condenser's cap p, and there condensed along with the exhaust steam from the engine, so that it serves to make up for the loss by leakage, &c., of the first supply. As the apparatus is of use only where the water for generating the steam is impure or salt, some mode is required for keeping the tank x clear of the deposit of these impurities, as by evaporation all these must collect in the evaporating vessel, according to laws well known. To remedy this, the evaporating vessel is connected with the box h by a pipe z''—said pipe entering the evaporator near its bottom, and discharging into box h, as shown. A cock or valve is also fitted into said pipe, to regulate the rate of discharge, which takes place by gravity alone, as the two vessels are alike in vacuo. The saturated water will flow through the pipe z'' in the same manner as if x and h were both open vessels. If the supply for waste is to be made up from salt water, as in sea-going steamers, then a certain quantity of this water must be taken out of the tank by this pipe proportionate to the quantity evaporated, and thus the amount fed through the pipe z must be sufficient for both the evaporation and the quantity thus drawn off. The same rule applies to evaporating water containing lime or any other impurity. The water taken off through z'' enters the box h, and is pumped out with the condensing water by the air-pump l.

In fig. 909 is a view of a modification of a condensing apparatus—the same letters referring to the same parts, except where otherwise indicated. This is to show a mode whereby the radiating or surface condenser may be immersed in the condensing water, or showered at pleasure, and exhibits also a

variation whereby the pump removing the water resulting from the condensed steam may be dispensed with.

In this case, when the pipes or other surfaces, n, are immersed in the water, they are subjected to the pressure of the same in a greater or less degree, according to its depth; but they are not subjected to the pressure of the atmosphere in addition, as will be shown. h' h'' represent two openings in h connecting the air-pump l by the channel k. k' k'' are valves for closing the openings h' h'', operated from the outside of the box h, as shown. If the pipes n are to be used submerged, the valve k'' must be closed, and valve k' opened. The condensing water being let on, fills up the box h until the water is on a line with the opening h', and thus the pipes are immersed.

If the pipes are to be showered instead, then k'' must be opened, and the condensing water let on to the plate m, in the manner before described. When this plan is adopted, the aperture for insuring the equilibrium must be placed in such a situation that the condensing water cannot enter the pipes; in fig. 909 it is shown at the pipe w', and w'' is the stop or valve for opening or closing it. The next feature is a method of dispensing with the pump w. A is a tank air and water-tight, and capable of sustaining the pressure of the atmosphere. This is to be connected to t by a pipe, with a valve or cock intermediate, as $t.'$ At t'' is a delivery cock; at t''' is an air cock. The pump u being disconnected, t' is to be opened, and thus communication is made between the tank A and pipes n, as plainly shown—t'' and t''' being closed always when t' is opened. The water from the condensed steam will now descend by its gravity, into A; when A is full, t' must be closed—t'' and t''' opened, which permits the water in A to run out, being collected in reservoirs, from which the boilers are to be fed. As soon as A is empty, close t'' t''', and open t' until again filled, and so on. The periodic opening and closing of these valves or cocks can be easily arranged to be operated by the works themselves.

Fig. 908 exhibits another arrangement, embodying however, the same general principles. The same letters are used to represent similar parts, described in the other figures. The principal variation in the construction of this part of the invention, consists in forming the box h, so that the tubes n shall be inserted in the two opposite sides, as shown in the dotted lines. In that case the caps p and r to cover them, are placed outside. The injection-cock o is placed at the bottom, and the delivery-pipe at the top, so that the pipes are shown as immersed in the water, but may be showered by making the changes before described. w''' represents a pipe forming a communication with the box h, and the interior of the pipes n, for keeping the pressure equal, and is equivalent to the aperture w, in figure 3, or w' in figure 5. Another variation consists in the manner of removing the water of the condensed steam, the same principle being applicable to removing the condensing water also. The pump u being taken off, a pipe a' is substituted which is attached to the cap r, where the water from the condensed steam accumulates. This pipe must have a descent vertically, sufficiently great to cause the column of water to counterbalance the atmospheric pressure (say of 34 feet), and may terminate in a reservoir. By this means the gravity of the water will overcome the vacuum in the pipes, and thus deliver itself without other mechanical aid.

The advantages to be derived from this invention are as follows:

First.—By arranging the radiating or surface condenser, so that it is not subjected to the pressure of the atmosphere. Secondly.—By reason of which arrangement, the apparatus is not so liable to be destroyed by the great pressure it would otherwise have to sustain; therefore durability and safety is increased. Thirdly.—Small leaks and fractures will not affect its operation; the box h being exhausted of air or other uncondensable gases, which are not therefore present to flow through such apertures, and the condensing water will not enter, because there is no external pressure upon the pipes, to force it in; the water falling upon the pipes by gravity alone, its tendency will be to run out rather than in. Thus, where salt or other bad water is used for condensing, no admixture of the pure water of the condensed steam will take place. Fourthly.—Increased safety; as the whole surface condenser might be destroyed in the box h, without impairing the working of the engine, or even arresting its motion. The only change perceivable would be the loss of fresh water, resulting from the condensed steam. This is a most important feature for seagoing steamers.

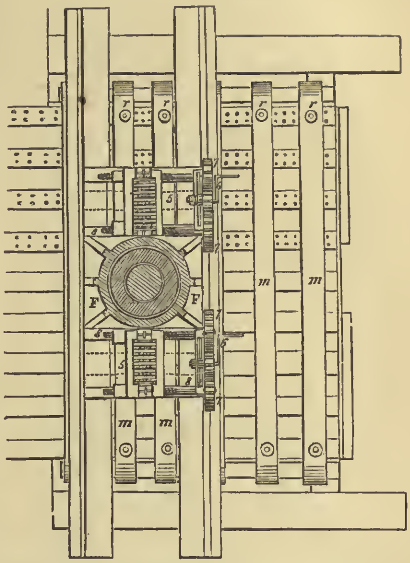
CONWAY TUBULAR BRIDGE. The great engineering event for 1848 is the raising of the Conway Tubular Bridge, and which, after so much fear and anxiety, has been effected with great success. This work derives its importance not so much from its greatness, as from its opening the way for the adoption of a new system of bridge building, whereby the resources of engineering are very much extended. To build a bridge greater than those which have been made before, to make a railway longer than those which have yet been opened, or to construct a more powerful locomotive, is a great work; but it is of much greater importance to execute something entirely new. The engineer who has constructed the greatest lighthouse or the greatest dock in his day, may be overcome by some one else, and then his claim is at an end; whereas, the engineer who extends the resources of his art, has a clear and unique claim to distinction. Mr. Robert Stephenson has the merit of carrying out this system of tubular bridge building, and it will be a special event in his career, beyond the many works of constructive skill he has already produced. The success of the Conway Bridge is none the less important, because it settles the practicability of that greater undertaking, the Menai Tubular Bridge. Thus progress in any one direction leads most certainly to greater exertion; and it is peculiarly necessary to give every encouragement to all attempts, which open a new career for the engineer, and give him greater means of exertion.

We have thus given engravings of the tube and the lifting apparatus, and shall lay before our readers drawings of the ingenious Jacquard machinery, invented by Messrs. Roberts, for punching the plates (See Jacquard Punching Machine.)

The construction, when finished, is to consist of two tubular bridges, formed of wrought-iron plates, each tube being for one line of rails. We shall now confine ourselves to the description of one of the tubes, which was fixed in its place in March, 1847, and is shown in the accompanying engravings

Fig. 907 exhibits a transverse section of one of the tubes and the masonry of the pier, together with the lifting apparatus. Fig. 908 is a side elevation of 19 feet in length of the tube, resting on the masonry, and the lifting apparatus. Fig. 909 is a section through 12 feet in length of the tube, and section of the lifting apparatus. Fig. 910 is a plan of the top of the tube to the extent of 20 feet in length, and plan of the hydraulic press. Fig. 911 is a front view of one end of the suspension girder, and Fig. 912 a side view.

910.



The tube consists of a shell or external casing, *a a*, of wrought-iron plates, from 4 to 8 feet long, and 2 feet wide by half an inch thick in the centre, and five-eighths of an inch thick towards the end of the tube, riveted together to T-angle-iron ribs, placed on both sides of the joints, and angle-gussets at the feet of the ribs to stiffen them; a ceiling, composed of 8 cellular tubes *b*, each 20¼ inches wide, and 21 high; and a floor containing 6 cellular tubes *c*, 27½ inches wide, and 21 inches high. The whole length of the tube is 412 feet, and 22 feet 3½ inches high at the ends, and 25 feet 6 inches high in the centre, including the cellular tubes at the top and bottom, running the whole length, and 14 feet wide to the outside of the side-plates. The upper cells are formed of wrought-iron plates, three-fourths of an inch thick in the middle, and half an inch thick towards the ends of the tube, put together with angle-iron in each angle of the cells; and over the upper joints is riveted a slip of half-inch iron, 4½ inches wide. The lower cells consist of three-quarter-inch iron plates for the divisions, and the top and bottom of two thicknesses of plates, each 12 feet long, 2 feet 4 inches broad, and half an inch thick in the centre, and one-fourth of an inch thick at the ends, and so arranged as to break joint; and a covering plate of half-inch iron, 3 feet long, is placed over every joint on the underside of the tube. The external casing is united to the top and bottom cells by angle-iron, on both the inside and outside of the tube, as shown in Fig. 912.

The ends of the tube, where it rests on the masonry, are strengthened by cast-iron frames *d*, to the extent of 8 feet of the lower cells; 6 cast-iron transverse I-shaped girders *e*, on the floor; 6 similar girders *f*, above; and upright cast-iron stanchions *g*, on each side of the tube, to which are bolted the ends of the girders, top and bottom, and also the cross-lifting girders *h*.

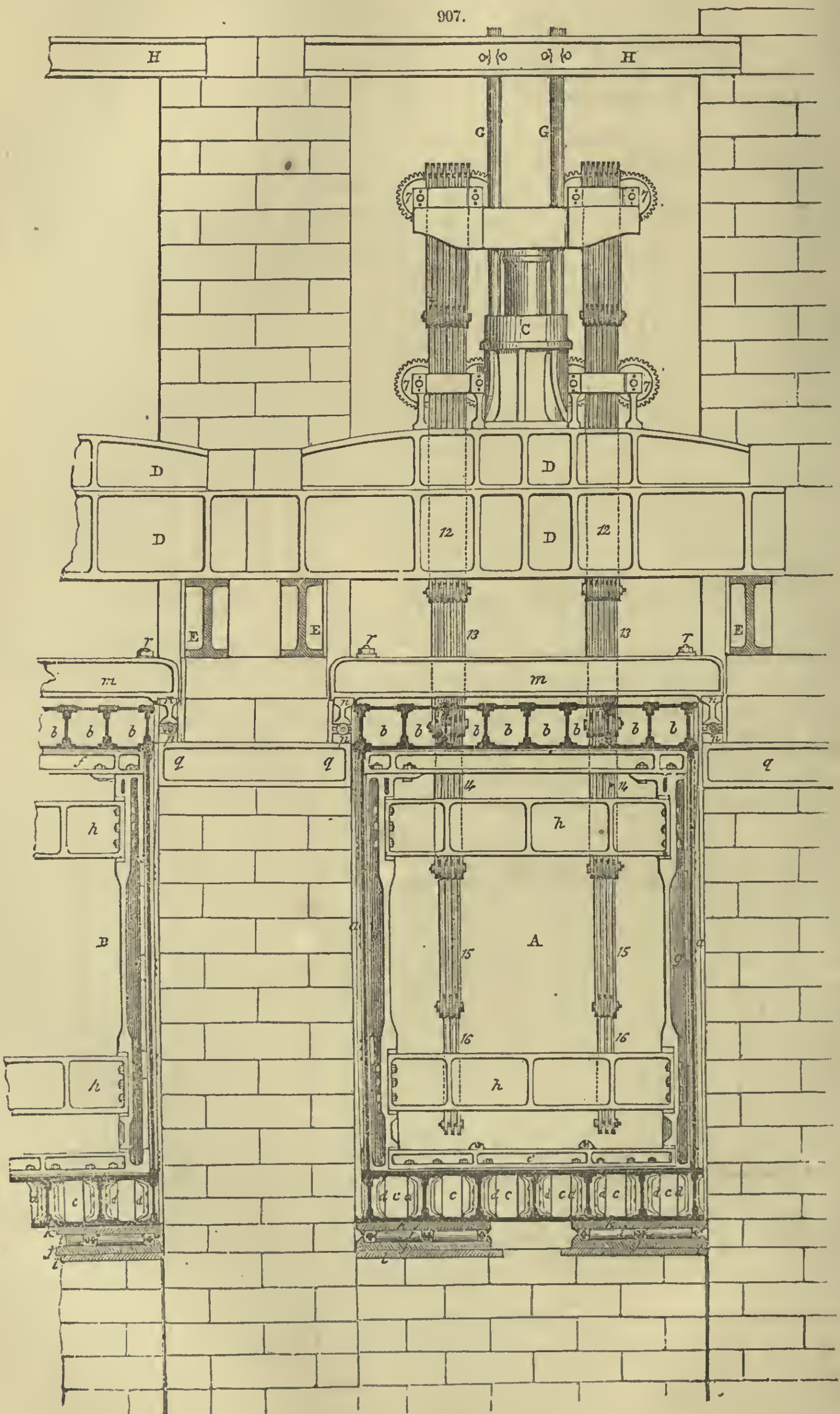
In order to allow of the free expansion and contraction of the tube, the ends rest on 24 pairs of iron rollers *i*, connected together by a wrought-iron frame, and placed between two cast-iron plates *j k*, 12 feet long by 6 feet wide, and 4 inches thick. The lower plate is laid on a flooring of three-inch planks *l*, bedded on the stonework; and the tube is also suspended to 6 cast-iron beams *m*, the ends resting on longitudinal bearers *n*, 12 feet long, with a circular groove on the under side, supported by 12 gun-metal balls *o*, 6 inches diameter, standing upon an iron bed *p*, and supported on the ends of the cast-iron bearers *q*. The tubes are suspended to the beam *m*, by wrought-iron bolts *r*, and spade-pieces riveted on to the sides of the tube, as shown in Figs. 911 and 912.

The lifting apparatus for raising this enormous weight was intrusted by Mr. Stephenson, to Messrs. Easton and Amos, engineers of the Grove, Southwark, to whom great credit is due for the very successful manner the tube was lifted. The machinery consisted of two steam-engines, erected in the recesses B of the corresponding tube, one on each side of the river; and each engine has a horizontal cylinder, 17 inches diameter and 16 inches stroke, with piston-rods working through stuffing-boxes at each end of the cylinder; each piston-rod has a cross-head, and gives motion by side-rods and cranks to two fly-wheels; and the ends of the two piston-rods work two forcing-pumps with plungers, $1\frac{1}{16}$ inch diameter, and 16 inches stroke. These pumps inject the water into the hydraulic press C, shown in the engraving, through the small tube 3.

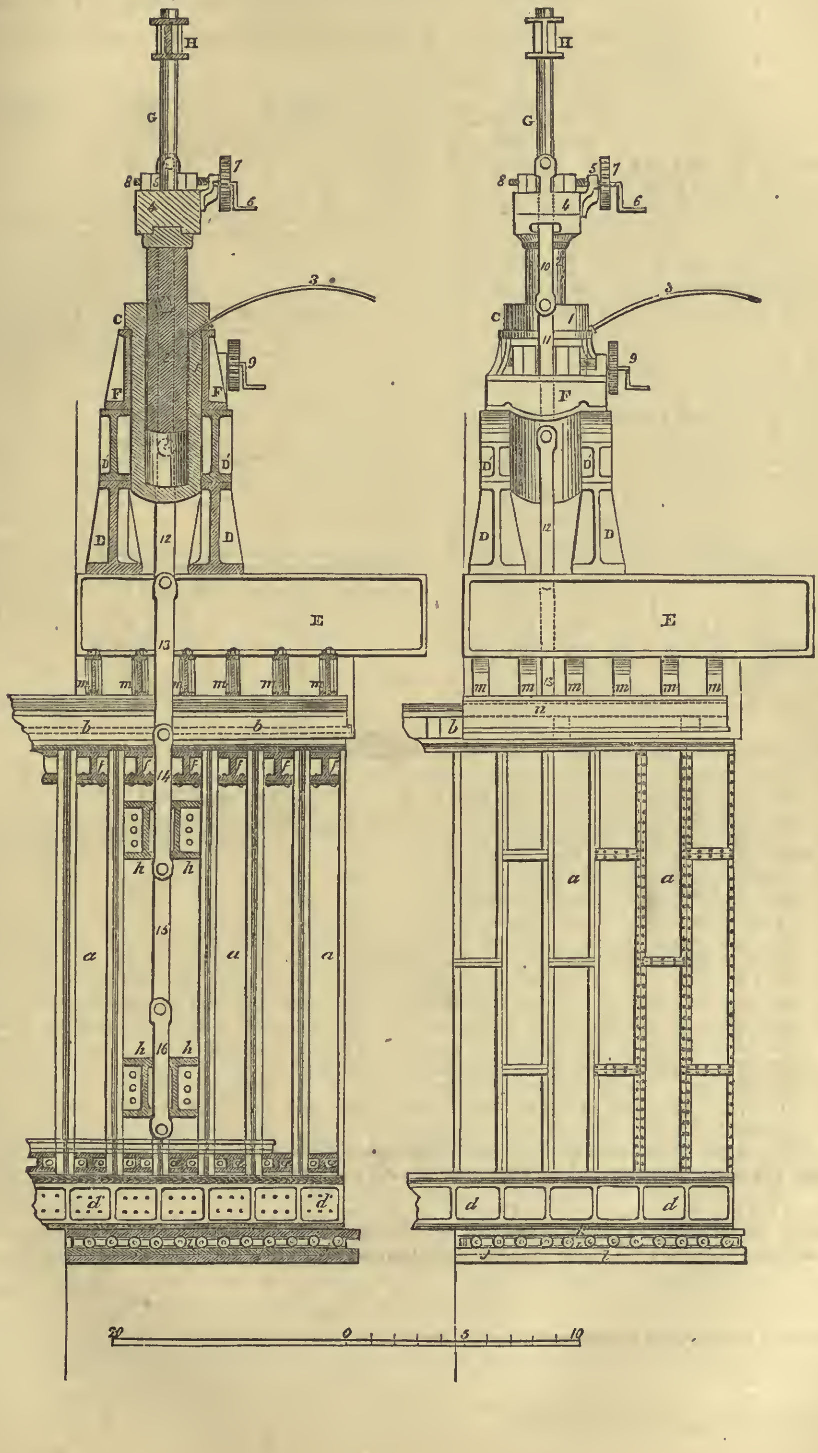
The press was erected on a stage constructed above the level of the top of the tube, and consisted of two cross-girders of cast-iron, each in two heights D, D′, the lower one 4 feet high, and the upper one 2 feet 6 inches high; the ends resting upon cast-iron bearers E, imbedded in the masonry of the piers. Upon the cross-girders was fixed the casing F of the ram, which is 5 feet 2 inches long, by 3 feet 9 inches wide, cast with ribs; and on the top of the cylinder are fixed two vertical guide-rods G, G, 6 inches diameter, passing upwards through the cross-head of the ram, and a cast-iron girder H, nearly at the top of the tower, and 18 feet above the girders D′.

The press consists of a cylinder, 1, firmly fixed in the casing, 37½ inches diameter externally, and 20 inches internally; and the ram 2, 18⅝ inches diameter, with a vacuity nearly seven-eighths of an inch all round, to receive the water injected from the pumps already described, through the tube 3, the orifice of which is three-eighths of an inch diameter; this tube is furnished with a lever-valve close to the cylinder, for safety, in case the pipes should burst. In the event of such a casualty, by an ingenious contrivance the lever-valve would be instantly closed, and the weight supported by the water in the cylinder. On the top of the ram is a cross-head 4, of solid cast-iron, 9 feet 10 inches long, 1 foot 10 inches deep, and 2 feet 4 inches thick, with two apertures, 2 feet 1 inch long, by 1 foot 1½ inch wide, through which the lifting chains pass; and on the top of this cross-head are fixed two clipping vices or clams, 5, 5, each consisting of a pair of wrought-iron jaws, 3 feet long, 11 inches deep, and 6 inches thick,

907.



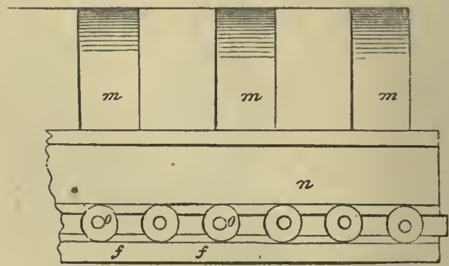
909. 908.



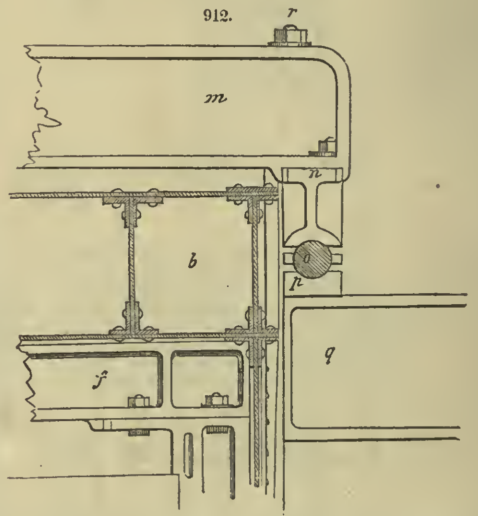
and a winch which turns a small pinion 6, that takes into two cog-wheels 7, 7′, fixed upon the heads of two horizontal screws, (8, 8′, left and right handed,) passing through nuts in the two jaws of the clams Thus it will be perceived, that as the winch is turned, the jaws are made to open or close, for the purpose of clipping the heads of the lifting chains; below these clams are two others 9, 9′, for clipping the heads of the lower links.

The two lifting chains consist of wrought-iron flat bars, in lengths of 6 feet from centre of bolt-eye to centre, and each bar is 7 inches wide and $1\frac{1}{8}$, $1\frac{1}{4}$, and $1\frac{1}{2}$ inch thick, with heads having shoulders fitted to the jaws of the clams. Each chain contained nine links of eight and nine bars alternately, besides the two lower links, each consisting of five and four bars. The heads of the first or upper links passed through the upper lifting clams, fixed on the top of the cross-head of the ram, and there secured by the jaws of the clams being screwed up taut; the second links passed through the lower clam, the jaws of which were left open, and the heads of the two lower links were made to abut against the under side of the lifting girders *g h*. When the pumps were set to work, the ram was lifted 6 feet, its full range; when it had attained this elevation the jaws of the lower clams 9, 9′ were screwed up close and clipped the heads of the third links 11, and there held the chain firm; the jaws of the upper clams were then opened, and the ram lowered down to its original position, when the bars of the top links 10 were removed. When this had been done, the jaws of the upper clams 5, 5′ were again brought under the heads of the second links, and screwed up taut, so as firmly to clip the shoulders of the links, the jaws of the lower vice 9, 9′ opened, and the ram was then set in motion to lift the tube another six feet, when the second links were removed as before described, and the operation repeated as above, until the tube had been lifted the height required, about 22 feet to 24 feet.

911.



912.



The power of the presses may be thus calculated: the area of the ram being equal to 337·64 circular inches, and the force acting upon the plunger equal to 2·14 tons per circular inch, the two being multiplied together give $722\frac{1}{2}$ tons, which is the force of one of the presses, and of the two presses 1445 tons. The actual weight lifted was estimated at 1,300 tons. The quantity of water used for each press is about 66 gallons.

The tube was constructed on a platform erected on the shore of the river, close to where it was to cross; and when finished, six pontoons, something similar to the large coal-lighters on the river Thames, were placed under the tube at low water, and which at high water lifted the tube off the piles upon which the stage was erected. It was then floated to its destination, and placed between the two towers, part of the masonry being left undone until the tube was put into its proper position, and as it was raised the masonry was built up under the tube. The time occupied in raising the tube and building up the masonry occupied four days; the actual space lifted per hour was 13 feet.

COP-SPINNER. *George H. Dodge's Improvements in Machinery for Spinning and Winding Yarn.*—This is a combination of the self-acting mule and throstle, and has many advantages over the common method of spinning, and is equally applicable for filling and warp yarn. In the room usually occupied for 1,000 mule spindles, 1,500 may be placed, which will do the work of 3,000 spindles. It occupies the usual space required for warp spinning, but will spin 50 per cent. more yarn to the spindle than the best ring-bobbin spinning known to us in use, and with a saving of two-fifths of the power. It will spin 100 per cent. more yarn than the flyer spindle, and with one-half the power, compared to the quantity. There is a great saving in expense, by dispensing with bobbins. The spindle is more durable than the common one in use, being tapered to the top; and there being no bobbins or check-pins used, it maintains its balance at any speed required. It is not liable to get out of order. It is much more convenient to piece up the ends when broken, than the bobbin-frame. One cent per spindle is paid for tending warp-frames, and $1\frac{1}{2}$ cent for filling-frames, and twelve dollars extra for doffers, per week. The proprietors, Messrs. John C. Dodge & Sons, of Dodgeville, Attleborough, Mass., have their entire mill upon this method of spinning, and from 29 years' practical experience with other spinning, believe it to be the best in use.

The following table exhibits the comparative product and cost of their old plan of spinning with that of their present improved cop-spinner:—

Bobbin throstles and mules, 4,600 spindles.

1847, 19 weeks product......	25,775 lbs. warp,		......cost, $1,116 69
	23,831¾ " filling,		
1848, " " "	25,974 " warp,		...... " 1,051 78
	24,523 " filling,		
	2)100,103		2)2,168 47
Average, " " "	50,051¾ "		" $1,084 23

Cop-spinner, 2,320 spindles.

1849, 19 weeks product......	32,704 lbs. warp,	
	28,574⅓ " filling,	
	61,278⅓ "	at a cost of $845 50.

The yarn was No. 30, and the average skeins per spindle daily, was seven, no allowance being made for stoppage.

The specification of the patent states, that the peculiar object of the improvements which are applied to a throstle spinning-frame, is to wind the yarn, as fast as twisted, or when properly twisted, upon each of the spindles in a regular or proper shaped cop, which shall have a binding-thread between each two adjacent layers of yarn, in order to prevent the cop from falling apart when removed, or while being removed from the spindle.

Fig. 913 exhibits a front elevation of the improved throstle-frame. Fig. 914 is an end elevation. Fig. 915 is a horizontal section, taken through the axis of the main drum, which drives the spindles and scroll-shaft; the other parts below the plane of the section being represented in top view. Fig. 916 is a rear elevation of the frame, with the exception of those parts of the mechanism which are situated above the tops of the spindles, and which are like those in common use in throstle-frames. Fig. 917 is a vertical section of the scroll-shaft and parts connected with it.

In the several figures, A A denote the cast-iron ends of a throstle-frame; B B are the step-rails of the spindles; C C, the upper bearing rails of the spindles; D D D, &c., are the spindles; E, the main drum by which they are driven; F, on each side of the frame, is the copping or ring-rail; G G, &c., are the guides to the threads in their passage from the front pair of drawing-rollers to the spindles; H is a series of drawing-rollers, such as are in use in other throstle-frames; I is the bobbin-frame or creel; K is the main driving-shaft, from which the drawing-rollers and other parts receive their motions; L is termed the scroll-shaft—it is situated beneath the main shaft, and extends transversely across the machine, and revolves in bearings *a a*, fastened to the step-rails B B. It is also supported by, and revolves in, a third box or bearing *b*, secured to a sustaining bar *c*, ends of which are respectively fastened to one end A of the main frame, and a transverse beam *d* extending from one lower girt *e*, on one side of the frame, to the other *f*.

The scroll-shaft has a reciprocating partial rotary motion imparted to it; it being made to move first in one direction, viz. forwards, with a slow motion, and next in the other direction or backwards, with a much faster one.

A dog or clutch wheel *g* is fixed upon a hollow shaft *h*, made to run loosely upon the scroll-shaft, in the position as seen in Figs. 915 and 917. The said shaft *h* has a worm-geer *i* fixed upon it, which is made to engage with an endless screw or worm *k*, attached to the lower end of a vertical shaft *l*, supported by and made to revolve in suitable bearings. On the upper part of the said shaft *l* is a spur-geer *m* fixed upon it, which is made to engage with, and is turned by a pinion *n*, fixed on another vertical shaft *o*: see Fig. 914. The said shaft *o* turns in proper bearings and has a spur-geer *p* fixed upon it, which geer is made to engage with a spur-geer *q* fixed upon a third vertical shaft *r*, put in motion by two bevelled wheels *s t*, the former of which is placed upon it, and the latter upon the main driving-shaft *k*. Consequently, when the main shaft is put in revolution in the direction denoted by the *arrow u*, in Fig. 914, motion will be given to the clutch or dog wheel *g*, in the direction denoted by the *arrow v*.

The clutch-wheel *g* consists of a circular plate, having a series of projections *w w*, &c., disposed at equal distances, as seen in Fig. 918, which is a side elevation of the dog-wheel, as removed from the scroll-shaft.

The teeth *w w*, &c., project over the periphery of a circular plate *y*, which is fixed upon a hollow tube *b′*, screwed to the scroll-shaft, and has a recess *z* cut in it, (as seen in Fig. 919, which is a side view of the plate *y*,) for the reception of a spring-dog *a′*, the spring of which is secured to the hollow hub *b′*. A bent lever *c′* is made to turn upon a screw-pin *d′*, inserted in the face of the plate *y*. The said lever should be so curved as to rest against the spring of the dog *a′*, and when its outer end is elevated, to press against the spring of the dog, and move it and the dog inwards, or out of one of the spaces *x* of the dog-wheel and into its recess *z*. A standard *e′* is fixed to the side of the frame for the lever *c′* to rest on.

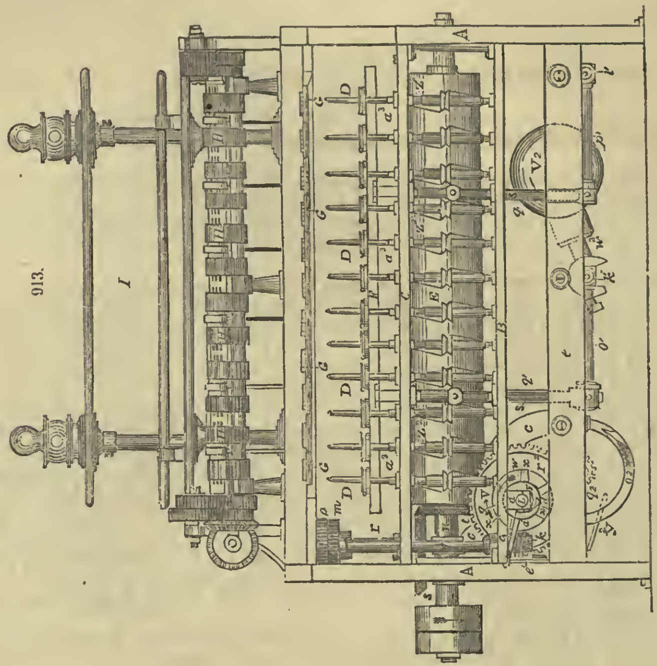
From the above it will be seen, that while the dog remains in any one of the spaces *x x*, &c., of the dog-wheel, the said dog-wheel will be so clutched to the scroll-shaft as to put the shaft in motion when the dog-wheel is rotated. When thus put in motion the shaft will continue to move until the lever *c′* is so borne against the stud *e′* as to press the spring-dog inwards, and out of the space *x*, in which it may happen to be.

The scroll-shaft will be then unclutched from the dog-wheel, and left free to move in an opposite direction, and will drag the spring-dog around with it until it meets the succeeding notch *x*, and springs into it, and by so doing, again clutches the dog-wheel to the scroll-shaft.

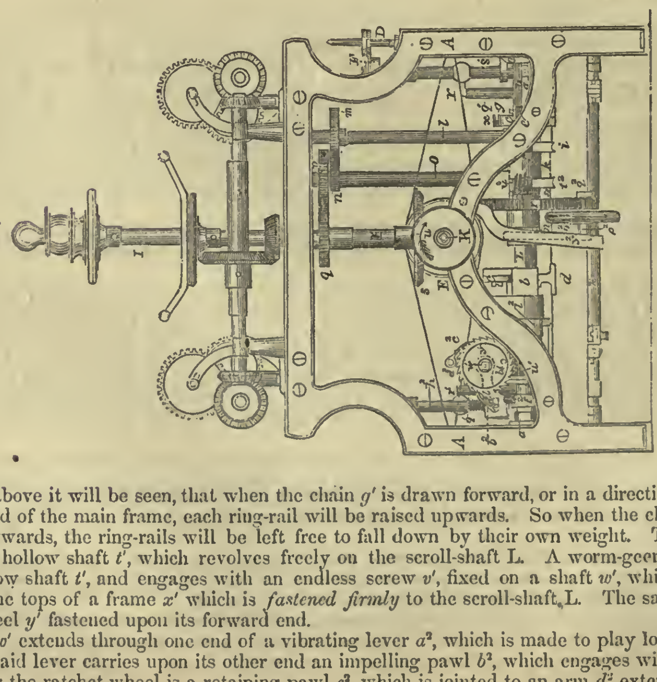
On the scroll-shaft is a cam or scroll *f′*, Fig. 920, made to move freely on the shaft. This cam has a chain *g′* attached to it, Figs. 920 and 915. The chain is carried horizontally over a guide-pulley *h′*, and thence downwards, and is connected to an arm *i′*, which projects from a horizontal transverse rocker

shaft k'. A similar transverse rocker-shaft l' is arranged parallel to the shaft k'. From each of the shafts k' l' an arm m' extends upwards, and is jointed to a horizontal connecting-rod n'. Each of these shafts has also two other arms o' o', or p' p', extending from it, Fig. 915. To each of these last-mentioned arms one of four vertical rods q' q' q' q' is jointed. Each ring-rail F is indirectly supported on two of the rods q' q'; that is to say, small studs r' r', from its vertical guide-rods s' s', rest upon the tops of said rods.

913.



914.



SCALE.—1 foot=1 inch.

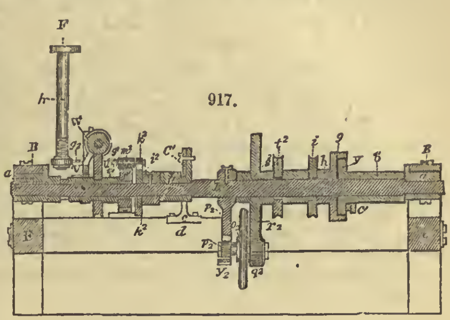
From the above it will be seen, that when the chain g' is drawn forward, or in a direction towards the right-hand end of the main frame, each ring-rail will be raised upwards. So when the chain is suffered to move backwards, the ring-rails will be left free to fall down by their own weight. The scroll f' is fixed upon a hollow shaft t', which revolves freely on the scroll-shaft L. A worm-gear u' is fixed on the said hollow shaft t', and engages with an endless screw v', fixed on a shaft w', which revolves in bearings in the tops of a frame x' which is *fastened firmly* to the scroll-shaft L. The said shaft w' has a ratchet-wheel y' fastened upon its forward end.

The shaft w' extends through one end of a vibrating lever a^2, which is made to play loosely upon the shaft. The said lever carries upon its other end an impelling pawl b^2, which engages with the ratchet-wheel. Over the ratchet-wheel is a retaining pawl c^2, which is jointed to an arm d^2 extending upwards

from the frame x'. The ratchet-wheel y' has a small crank-handle b^4 projecting from its side to turn the whole back and lower the ring-rail when the pawls are thrown up, and when desirable.

Directly under the rear end of the lever a^2 is a bent lever e^2, which turns upon the scroll-shaft as a fulcrum. Its outer end rests, when in its lowest position, on the top of a stationary standard f^2, affixed to the lower girt of the cast-iron end of the main frame. The inner arm of the said lever e^2 extends directly under a horizontal projection g^2 applied to a vertical rod h^2, extending downwards from the adjacent ring-rail F. The said projection g^2 should be so adapted to the rod h^2 that it may be elevated or depressed by adjusting-screws and nuts, in order that its position may be regulated as circumstances may require.

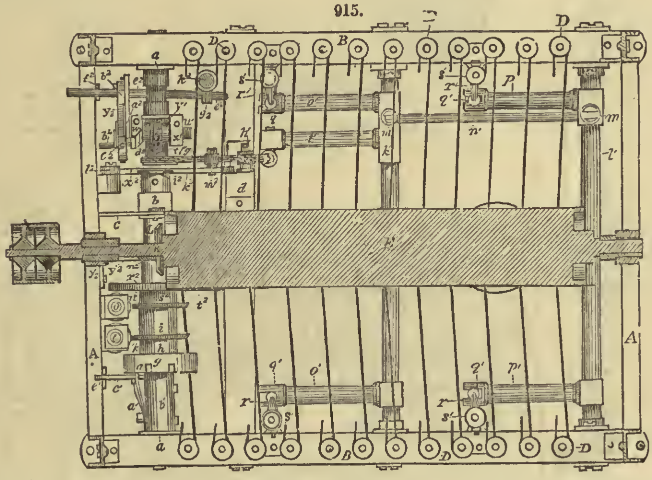
917.



The scroll-shaft has a cam i^2 fixed firmly to it. The said cam is seen in Fig. 921, which represents a section of it, and the lever beneath it. It also exhibits the chain g', and various parts adjacent thereto. The cam i^2 is made to act upon and depress a lever k^2, whose fulcrum is at l^2. The said lever carries a roll m^2, applied to the side of its inner end, and resting on the chain g^2.

Now in order that the ring-rail may not fall so suddenly as to break the yarns, or not put on the cop a sufficient quantity of binding-thread, some kind of mechanism becomes necessary to cause it to fall with the required velocity.

915.



SCALE.—1 foot=1 inch.

An arm n^2, fixed to the scroll-shaft L projects downwards from it, and carries a small fly-wheel o^2 on an axle p^2, extending horizontally from it. Said fly-wheel has a small pinion q^2 affixed to it, which engages with a spur-geer r^2 fixed to a tubular shaft s^2, which runs loosely upon the scroll-shaft. On the said shaft s^2 is a worm-geer t^2 which engages with an endless screw u^2, placed on the vertical shaft o, before mentioned. The said endless screw u^2 should so revolve the geer-wheel t^2 as to turn the shaft s^2 and the geer-wheel r^2 in the direction of the arrow on said wheel r^2.

The wheel r^2 will then act on the pinion, and put the fly-wheel o^2 in rapid revolution in the direction of the arrow; this taking place while the ring-rail is being raised, will cause a considerable momentum to be generated in the fly-wheel, which rises upwards with the arm n^2, which will be carried up by the forward movement of the scroll-shaft. Now when the ring-rail falls, the momentum so generated in the fly-wheel will be brought into action in such manner as to cause the pinion q^2 to so operate against its geer r^2, as to counterbalance in a certain degree the tendency of the ring-rail to fall too suddenly. The ring-rail will thus be eased down, so as not to break the threads, and with the degree of velocity necessary to insure the laying of a due quantity of binding-thread on the cops.

The ring-rail may be further counterbalanced by an adjustable weight v^2, applied to an arm w^2 extending from the rocker-shaft k'.

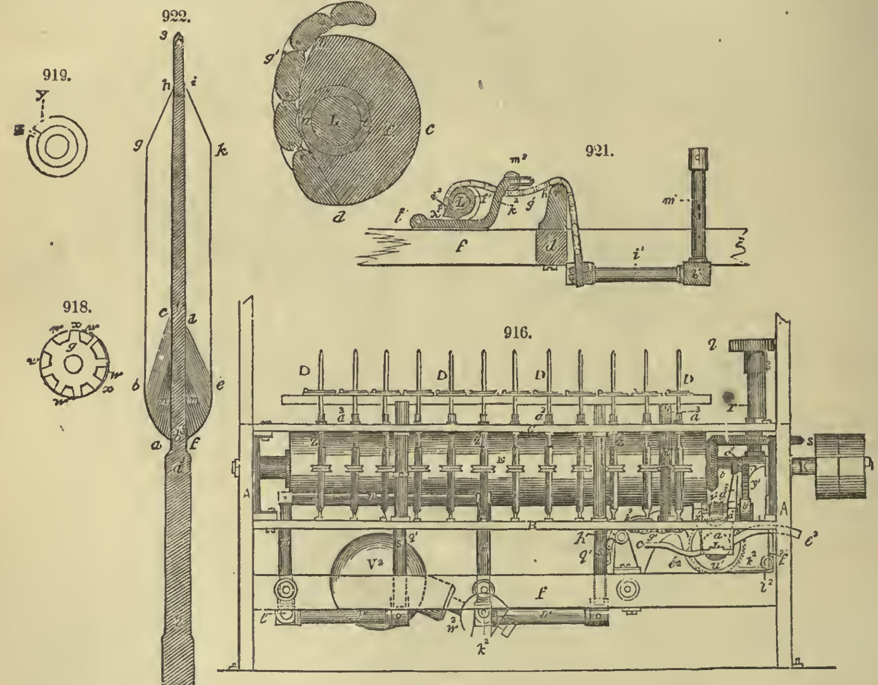
By means of the scroll f', the length of each successive layer of yarn composing the cop is regulated. The elevation of the ring-rail is gradually increased by the peculiar shape given to the scroll f', and the gradually turning said cam on the shaft.

Fig. 922 represents a longitudinal and central section of a cop, placed on a spindle l. The part $a\,b\,c\,d\,e\,f$ of the cop, is termed the *bottom part*, and all above, the top part. The first layer of yarn is wound on the spindle a distance $a\,n$, equal to about one half of the length $b\,c$ of the last layer composing the bottom part of the cop. From the above, it will readily be understood why the scroll or cam f' must be gradually turned on the scroll-shaft, so as to increase the length of each successive layer of yarn composing the bottom part of the cop.

It is the purpose of the worm u', endless screw t', shaft w', frame x', ratchet-wheel y', vibrating lever

a^2, impelling pawl b^2, lever e^2, standard f^2, projection g^2, and rod h^2, as before described, to produce the gradual rotation of the cam, both to form the bottom and top part of the cop. When the scroll-shaft is moved forward, the lever a^2 will be moved against the lever e^2, and thereby cause the impelling pawl b^2, to turn the ratchet-wheel y' a short distance, so as to create a movement of the scroll or cam f' on the scroll-shaft. The movement of the ratchet-wheel is increased by elevating the outer end of the lever e^2, which may be effected by depressing the adjustable projection g^2 of the rod h^2. Owing to the manner in which the scroll f' is made, it becomes necessary to turn it somewhat faster on the scroll-shaft at first, while forming the lower portion of the bottom part of the cop, than it does as the winding of the said bottom part continues to progress. In winding the top part of the cop, the scroll has a regular progressive motion upon its scroll-shaft, and the portion $b\,c\,d$, Fig. 920, of its periphery is then receiving and acting on the chain g'; while the bottom part of the cop is being made, the portion $a\,b$, Fig. 920, is in action upon the chain.

In order to cause the ring-rail to rise upwards with the increased velocity necessary to prevent the yarn from piling too much in one place, and thereby destroying the *conical* form of each layer of yarn, the cam i^2, lever k^2, and roll m^2, are used, the cam being so formed as to properly depress the lever k^2, to the extent required, to cause the roll m^2 to bear down upon the chain g', so as to produce the gradual increased rise of the ring-rail.



Scale.—1 foot=1 inch.

As it is very important that but very little yarn should be wound at the nose or upper part of each layer of the cop, the cam i^2 has an angular projection x^2, (see Fig. 921,) which as soon as the cam has completed its action in the lever k^2, shall in its turn depress the lever so as to cause a very sudden rise of the ring-rail sufficient to produce the effect required. A friction-spring y^2, at the end A of the main frame, acts as a stop to gradually check the motion of the arm n^2, when it falls down.

It often happens that the ring of the ring-rail may render it difficult to get hold of the end of the thread wound on the cop. In order to overcome this difficulty, the spindle, for about one inch and a half below its upper bearing, is made of the same size or diameter as the part which runs in the bearing, as seen at z^2, in Figs. 913 and 922.

By taking hold of the spindle when so made, it may be readily raised upwards, so as to carry the broken end of the thread above the ring of the ring-rail, and into such a position as will readily enable the operative to join the ends of the yarn when broken.

In order to obtain the advantages of a small spindle, and with a diameter at bottom large enough to start the traveller without danger of rupture of the yarn, the part a^3 of the spindle directly below that on which the cop is formed, is made of a diameter large enough to produce the lateral drag upon the traveller, required to overcome its inertia when first started, and give to it a velocity that will prevent the thread from breaking; and, before commencing the cop, a few turns of yarn are wound on the said part of the spindle. That part of the spindle on which the cop is formed, (viz. the part $b^3\,c^3$,) is made of as small a size as will be allowable and admit of its possessing the necessary strength.

The spindle so constructed is seen in the drawings. By this mode of making it, cops can be doffed without first being obliged to raise them upwards on the spindles by the hand far enough to allow of a

few turns of yarn to be laid on that part of each spindle on which the cop is first commenced, as is generally done in mule spinning.

A convenient velocity for the spur-geer r^2, is one revolution to sixteen of the front drawing-roller; and for the clutch g, at the rate of sixty-four one-hundredths of a revolution to eighty revolutions of the front drawing-roller. The patentee mentions these proportions, but does not confine his invention to such.

Mr. Dodge claims the combination of mechanism by which the scroll-shaft has a partial rotary forward motion imparted to it, and is allowed to fall or move backwards, the same consisting of the standard e^1, or any equivalent, the bent lever c', the spring-dog a^1, the clutch or dog wheel g, or their mechanical substitutes; the whole being arranged, applied to the scroll-shaft, and operated and made to operate together substantially. And in combination with the shaft, and machinery for imparting to it its rotative motion or motions, he claims the cam, and chain, and machinery connecting the shaft with the ring-rails. He further claims the combination of mechanism by which he is enabled to regulate the length of each successive layer of yarn composing the cop; the same consisting of the cam f^1, and made to rotate on the scroll-shaft; the worm-geer u', endless screw t', shaft w', frame x', ratchet-wheel y', vibrating lever a^2, impelling pawl b^2, lever e^2, standard f^2, projection g^2, and rod h^2, extending downwards from the ring-rail, or their mechanical equivalents; the whole being combined and made to operate.

Further, in its application to the scroll-shaft, the combination of mechanism by which the fall of the ring-rail is regulated in such a manner as to prevent it from descending too suddenly so as to break any of the yarns; the mechanism consisting of the fly-wheel o^2, and machinery for turning it, as applied to the scroll-shaft, and made to operate in connection with it. And for the purpose of causing the ring-rail to rise upwards with the increased velocity necessary to prevent the yarn from piling too much in any one place, and thereby destroying the conical form of such layer of yarn composing the cop, Mr. Dodge claims the cam i^2, lever k^2, and roll m^2, as combined with the scroll-shaft, and the chain g'. And in combination with the machinery, he claims the projection x^2, applied to the cam i^2, for the purpose of producing a very quick rise of the ring-rail, in order to finish the nose or upper extremity of each layer of yarn composing the cop. And he also claims the above-described manner of making each of the spindles, in order that it may be elevated so as to carry a broken end of yarn above the ring-rail, so that an attendant may readily seize it to piece up or join it to the thread proceeding from the draw-rollers, without being obliged to wait for the ring-rail to fall downwards.

He further claims the construction of the spindle directly beneath that part of it on which the cop is formed of a diameter proper to produce the lateral drag on the traveller, sufficient to overcome its inertia, and impart to it a velocity necessary to prevent the yarn from being broken in combination with making that part of the spindle on which the cop is formed smaller in diameter.

CORNISH BOILERS. See Boilers.

CORNISH ENGINE. A single acting beam engine, used for raising water: the steam is worked very expansively, and used for the down-stroke only, to raise an immense weight, fastened to the pump-rod, at the end of the beam: the steam having acted for the down-stroke, and the entrance-valve being closed, a communication is formed between the top and bottom of the cylinder, by lifting a valve in the steam passage, called an equilibrium valve: the pressures on the piston are thus equalized, and the weight acts to force the water up, and raise the piston.

Fig. 923 is a sectional elevation of the cylinder and valve geer, and fig. 924 a front elevation of the valve geer of a Cornish Engine.

A is the cylinder shown in section fig. 923. It is 70 inches internal diameter, and of such length as to allow of a 10-feet stroke of the piston. It stands on a large block of stone, and is bolted firmly down by four strong bolts to the masonry below.

The cylinder is enclosed in a jacket or casing of cast-iron, which is of such a diameter as to leave a clear space of one inch all around between it and the outside of the cylinder. This space is made to communicate with the boilers by a pipe a, about 4 inches diameter, by means of which it is kept constantly filled with steam, preserving thereby the cylinder at a high temperature. This is of peculiar value in the Cornish engine, as it tends to prevent the steam within the cylinder from having its temperature and pressure lowered in an undue degree, while expanding, by contact with metal cooled by exposure to the air. The heat of the jacket also checks any waste by condensation, and experience has proved that if the jacket is removed a considerable reduction in duty is the consequence.

The boilers being so placed that the water line is at a lower level than the bottom of the cylinder, the water produced by condensation in the jacket finds its way back again to the boilers at a high temperature, by the pipe a.

In order to prevent radiation and consequent loss of heat from the outside of the steam case, the whole is surrounded with an outer covering of wood (shown by dotted lines b, fig. 923,) leaving an interstice between the wood and the iron. This space is filled with some bad conductor of heat, such as sawdust or ashes.

In the best Cornish engines, the temperature of the outside casing does not exceed 70° or 80°, and the atmosphere of the engine house is frequently only a few degrees warmer than the external air.

The cylinder cover and bottom are also protected from the cooling influence of the air of the engine-house. The cover is fitted with a false lid or cap c, enclosing a thick layer of sawdust or other bad conductor, over the whole of the metal of the cover. The space d, under the bottom of the cylinder is kept constantly filled with steam by a branch from the pipe a_3.

The stuffing box on the cylinder cover, through which the piston rod passes, is of peculiar construction. In the middle of the packing, and dividing it into two horizontal layers, a small chamber is formed by two brass rings c c, fig. 923, kept apart by small pillars or distance pieces, and allowing the piston rod to slide freely through them.

Into this chamber steam is admitted by a small pipe from the jacket of the cylinder, the oject of the arrangement being to prevent any leakage of *air into* the cylinder. When the pressure of the steam within is below that of the atmosphere, which it always is during a large portion of the stroke during

expansion, such leakage, if it occurred, would be of consequence in spoiling the vacuum. The rings e e forming the chamber, have liberty to slide a little in the stuffing box when the packing is screwed down This ingenious contrivance was invented by Jonathan Hornblower.

The piston, piston rod, and parallel motion present no remarkable feature of sufficient consequence to render a description of them necessary.

The main beam is, as usual in large engines, cast in two plates, which are bolted together with distance blocks between, to keep them parallel with each other. The inner end of the beam or that to which the piston rod is attached, is generally longer in Cornish engines than the outer end, which carries the pump rods, giving a leverage of about 10 8 or 9, in favor of the piston. The object of the difference being to give the pumps a lower velocity then the piston, such being found in practice to be advantageous to their working.

There is a strong bar of iron called a *catch piece*, fixed transversely by brackets upon the upper part of the beam, and intended to prevent damage being done by the engine making too long a stroke in-doors. When the piston arrives at the bottom of its stroke, or as near to the cylinder bottom as it is thought prudent to allow it to travel, the bar touches the blocks fixed on the spring beams, and prevents its further descent. Otherwise the cylinder bottom might be broken by an increased length of stroke consequent upon an increase of steam admitted, or on an accidental detachment of some of the counter-weight by breakage of the pump-rod.

C is the plug rod for working the valves and cataract.

The plug rod is sometimes single and sometimes double, the latter is the case with the engine shown in this fig. The two rods are there marked C 2, and C 3, 4, both are seen, fig. 924. The two rods are connected at their upper extremity by joints with the back links of the parallel motion, and work through guides i i, by which means they are constrained to move in a vertical line. The rod C 3, 4, is lengthened at its lower extremity for the purpose of working the lever of the cataract, as will be explained.

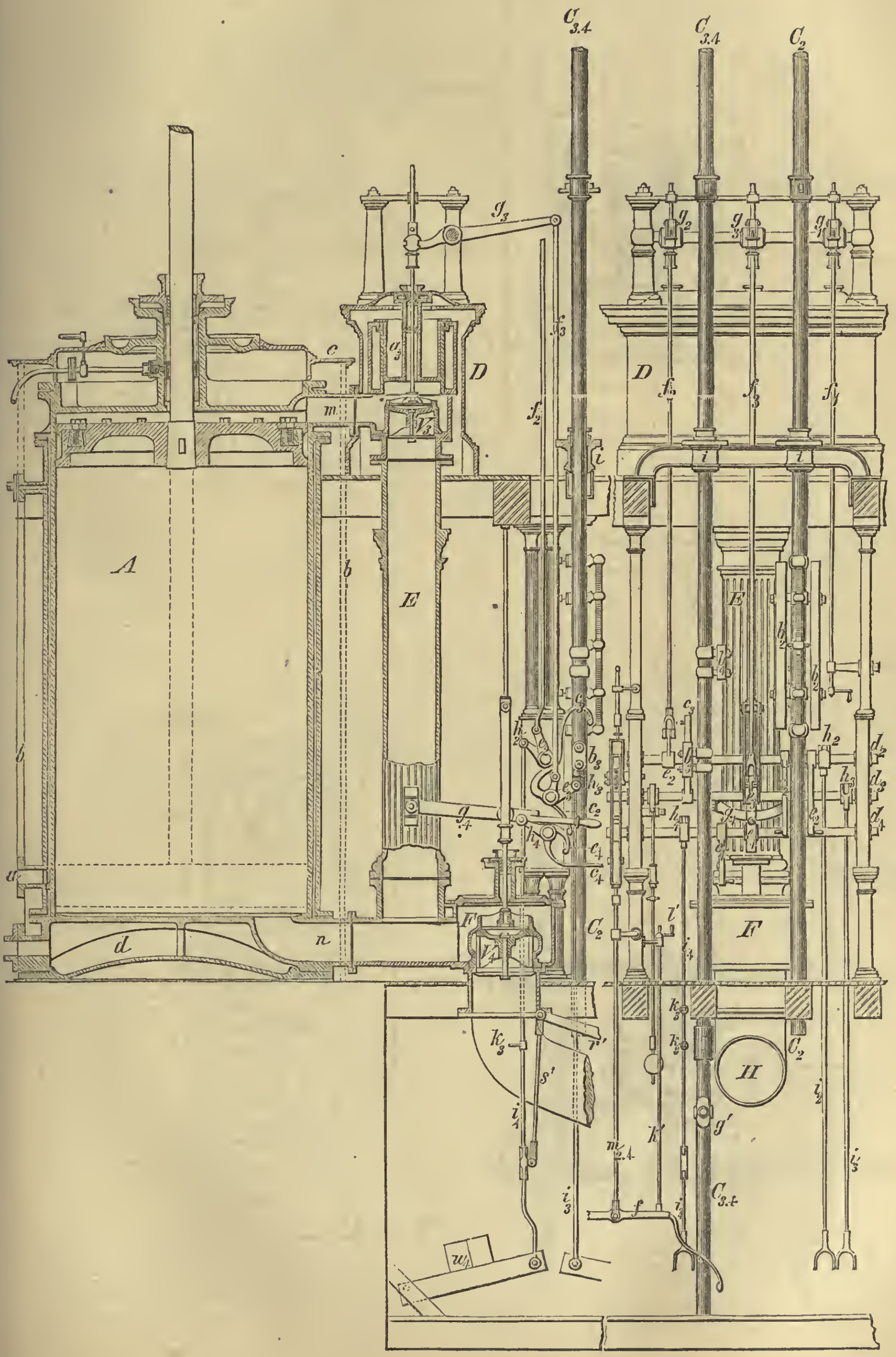
D is the top nozzle, shown on a larger scale and more fully in plan and section fig. 925-6. It contains three valves, viz. First; V_1, the *governor* or *regulating* valve, for regulating the admission of steam into the chamber k k of the nozzle, whence it afterwards passes through the steam valve V_2, into the cylinder. The opening of the governor valve is constant during the working of the engine, *i. e.*, it is not moved by the engine, but only occasionally by hand, for the purpose of regulation. It corresponds in some measure with that of the throttle or governor valve, in the rotative engine. By this means, although the pressure in the boilers may occasionally vary, the mean effective pressure in the cylinder may be maintained constant with great ease and precision. The motion of the governor valve is commanded by a handle placed within reach of the engine-man, and connected by a rod f_1 and lever g_1, with the stalk of the valve. The rod has a micrometer screw on its upper end, which works into a united socket attached to the end of the lever g_1, and thereby raises or lowers the valve. Second; V_2, fig. 925, Pl. V., the *steam valve*, for admitting steam into the cylinder. When this valve is raised (the governor valve being supposed open also), the steam finds a passage through it, from the nozzle chamber k k, into the space l, and thence by the upper steam port m into the upper part of the cylinder; the piston therefore descends, and the engine commences its in-door stroke. After the piston has travelled through a certain portion of its course, the steam valve is closed, by means hereafter described, and the communication with the boiler thereby cut off; the remainder of the stroke being accomplished by the expansion of the steam admitted. The steam passes through the chamber k k round the equilibrium valve, in the direction of the arrows (fig. 925), from the governor valve to the steam valve.

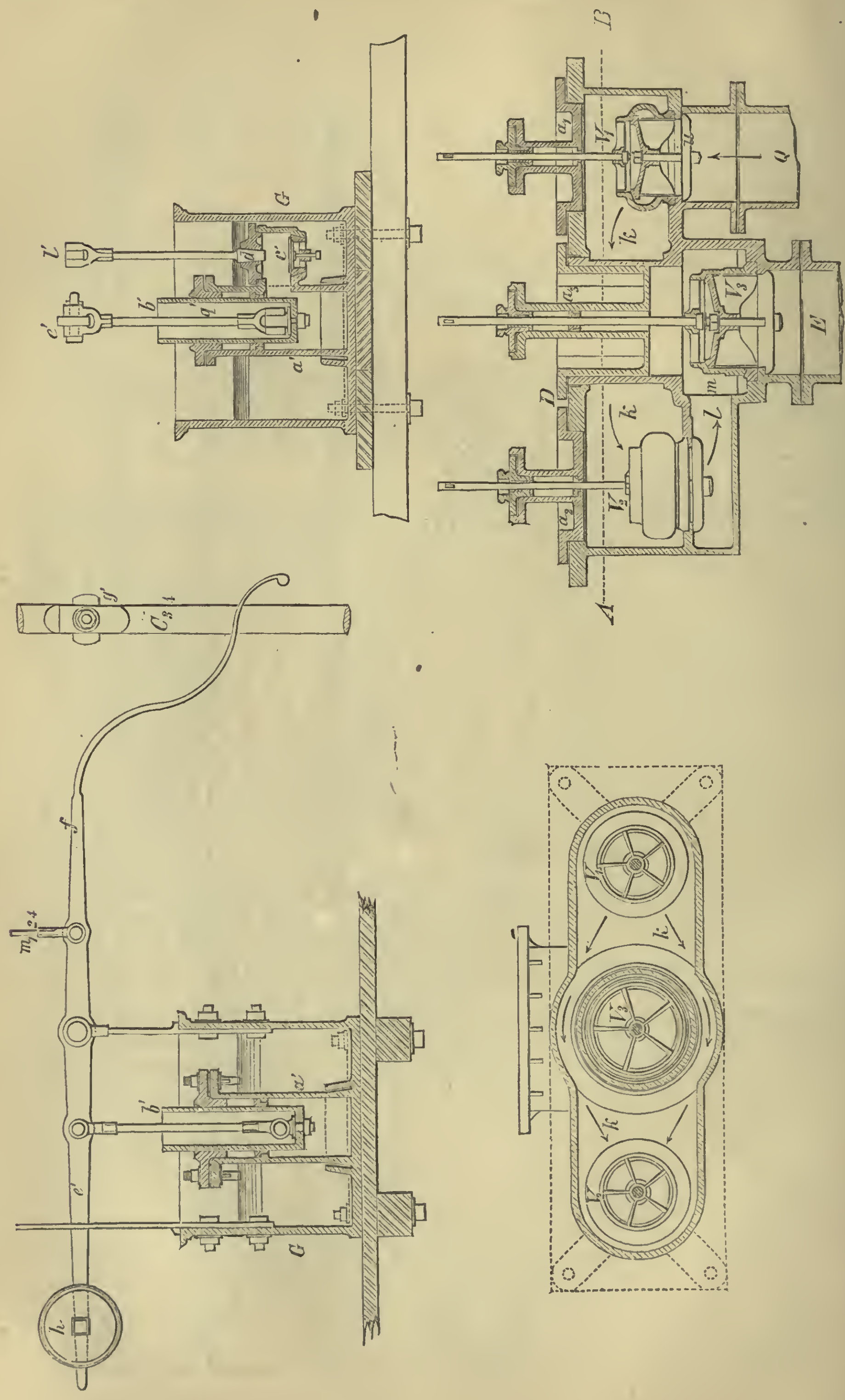
Third; V_3', situated in the middle of the nozzle, is the *equilibrium valve*, for opening the communication between the spaces in the cylinder above and below the piston. When therefore the valve is opened the steam above the piston will, by its excess of elasticity, find its way along the *equilibrium* pipe E, and by the lower port n, into the lower part of the cylinder, until an *equilibrium* is restored between the pressures above and beneath the piston, which then is at liberty to be drawn upwards by the preponderating weight of the rods hung at the outer end of the beam.

The top nozzle is, like the cylinder jacket, enveloped in an external casing, leaving an interstice all round, which is filled with sawdust or ashes to prevent loss of heat.

F is the bottom nozzle, seen in section fig. 923. It contains, V_4, the exhaustion valve, for opening or closing the communication between the lower part of the cylinder and the condenser. The nozzle chamber above the valve communicates with the cylinder by the lower port n, while to the *bottom* of the nozzle, under the valve, is attached the eduction pipe H, so that when this valve is lifted, the steam in the lower part of the cylinder has liberty to rush into the condenser, and a vacuum is thus formed beneath the piston. It will be remarked that the four valves last described are of a peculiar construction, being double-beat valves, (See VALVES), so called from their having two conical ground surfaces or beating faces, instead of, like the ordinary stalk valve, only one.

G is the cataract, fully shown in two sections, figs. 927-8, the use of which is to regulate the period of opening the steam and exhaustion valves, and thus to determine the interval between the successive strokes of the engine, that its rapidity of action may correspond with the quantity of water to be drawn from the mine. It consists of a barrel in which works a plunger, being in fact simply a small plunger forcing pump. The *inlet* is by a valve c' opening freely upwards, but the *outlet* is contracted at pleasure by a moveable plug d'. The pump is placed in a cistern of water G, and the plunger is attached by a joint to the arm e' of the lever e' f'. When the plug rod $C_{3\cdot 4}$, has descended nearly to the bottom of its stroke, a tappet g', upon the lower part of it strikes the end of the lever and thus raises the plunger, the water entering freely through the valve c'. When the stroke is finished, and the plug rod begins to ascend, the tappet g' quits the lever and the weight h', which is fixed upon the arm e', and has been raised by the preceding motion, becomes in its turn the motive power, tending to expel the water from the pump, by forcing the plunger





down. But the inlet valve before c', is closed, and the only exit for the water is by the aperture left round the regulating plug d'. It is evident therefore that the interval between the time the tappet g' leaves the cataract lever, and the commencement of the next stroke, depends upon the time occupied by the descent of the cataract plunger and ultimately upon the degree of opening given to the regulating plug d. This can be adjusted with great nicety by means of a micrometer screw and handle i (fig. 924,) connected with the regulating plug by the rod t and lever l.

H is the eduction pipe leading from the bottom of the exhaustion valve nozzle F to the condenser. This is double the area of the steam pipe. K is the condenser, L the air pump, the bucket of which has a stroke of half that of the piston. N is the feed pump, of the plunger description.

From Hughes we extract the following formula for the proportions of the cylinder. $a = \dfrac{W}{p\,v}$ a being the arc of the cylinder in square inches, W the work to be done, or the lbs. to be raised 1 foot high; p the pressure per square inch on the piston, and v the velocity in feet per minute. From numerous examples among the best machines, from 850 to 1,200 may be assumed as the value of $v\,p$.

Table showing the value of $v\,p$, from the actual working of fifteen Cornish Engines in 1855.

No. Name of Engine or Mine.	Average number of strokes per minute.	Length of stroke in feet.		Velocity of piston in feet per minute or value of v.*	Load per square inch on piston $= p$.	Value of $v\,p$ or continued product of number of strokes per minute, by length of stroke, by load in lbs. per square inch.	Average duty for the year expressed in millions of lbs. raised 1 foot high by consuming 1 cwt. of coal.
		ft.	in.				
1 Boscundle . .	6·9	9	0	62·2	13·4	833	52·9
2 Gt. Dev. Consols	3·6	9	0	32·0	29·4	941	49·2
3 Fowey Consols	6·6	10	4	67·7	13·8	934	98·6
4 Great Polgooth	6·3	10	0	63·0	17·7	1115	93·9
5 Ditto . . .	6·4	10	0	63·6	11·4	725	70·1
6 Mary Ann . .	6·2	7	0	43·7	18·2	795	42·4
7 Par Consols .	4·8	12	0	57·3	13·6	779	98·5
8 Ditto . . .	5·2	9	3	48·3	11·9	575	76·2
9 Pembroke . .	2·9	10	6	30·4	17·6	535	76·7
10 Ditto . . .	4·9	10	0	49·5	19·1	945	76·2
11 South Caradon	6·4	9	0	57·7	12·0	692	49·1
12 Ditto . . .	5·5	9	0	49·3	13·4	661	48·2
13 Trelawny . .	4·7	10	0	47·1	17·3	815	67·4
14 West Fowey .	3·8	10	0	37·8	12·1	457	70·4
15 Wheal Uny .	4·1	11	0	44·7	17·0	760	71·3
						Average 771	

* The velocities in this column are the average monthly velocities, and are not always the product of the two first columns because the average number of strokes is only carried to one place of decimals. The velocities, however, are strictly correct.

CORN-MILL. By William Fairbairn, Manchester. Among the mechanicians who have contributed to the improvement of that description of machinery now under consideration, Mr. Fairbairn, of Manchester, occupies a most distinguished position, and accordingly, we find that he is most extensively employed in the erection of corn-mills throughout all parts of the continent of Europe. The example which we have chosen for detailed illustration is a small mill of three pairs of stones, erected by him for His Excellency the Seraskier Halil Pacha, of Constantinople. It is interesting, as exhibiting, within a small compass, an epitome of all the processes carried on in larger establishments, and thereby enabling us to show the mechanism by which these processes are effected on a larger scale than we could otherwise do.

Enumeration of the Figures.—Fig. 923 is a sectional elevation of the mill, the line of section being taken in a longitudinal direction, and exhibiting the position of the stones, the engine, and driving geering, and of such portions of the subordinate apparatus as are visible on the side of the mill which is exposed to view.

Fig. 924 is a sectional plan corresponding to the above, and taken on a horizontal line passing through the lower story of the mill.

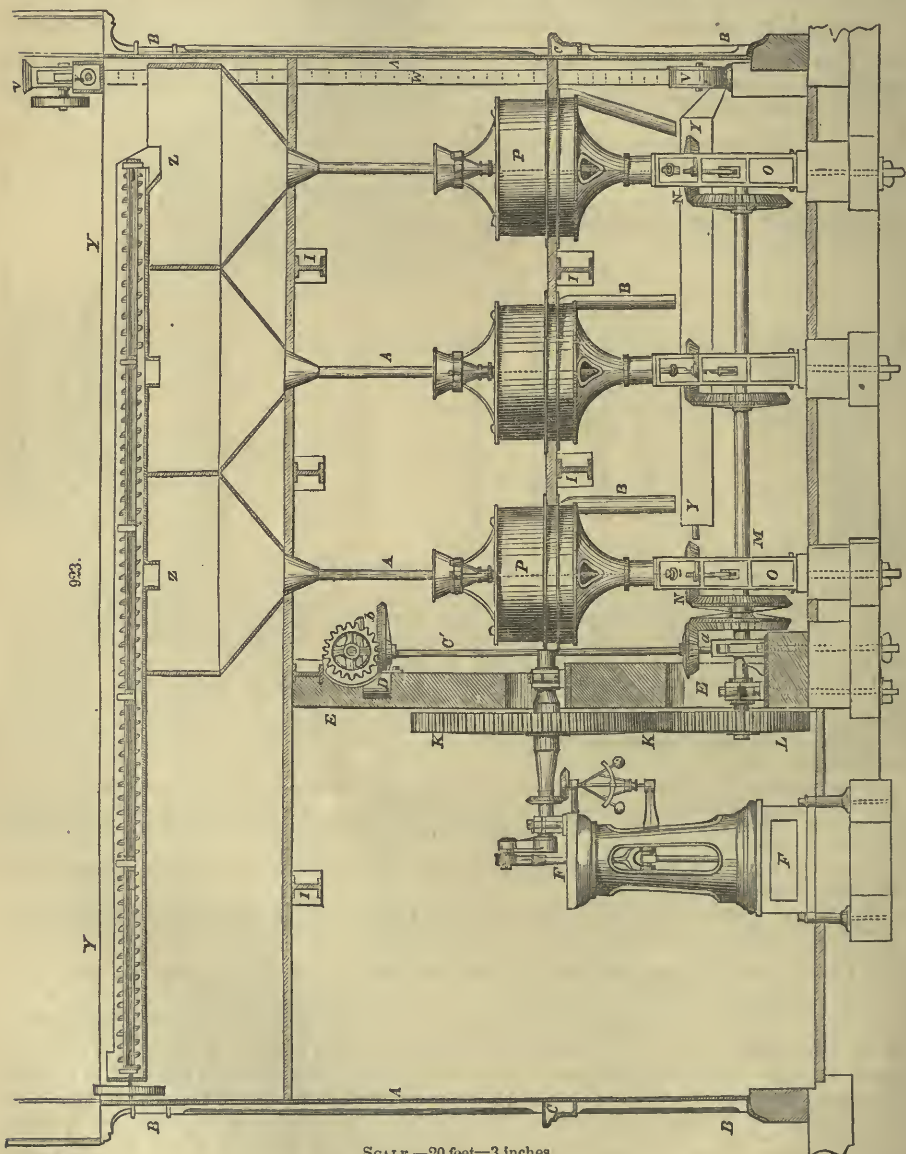
Fig. 925 is a transverse section of the entire mill, in which are shown the garners for undressed and dressed wheat, the mechanism by which it is cleaned and conveyed from the former into the latter, the sack-tackle, &c.

Fig. 926 is a sectional plan corresponding with the plan Fig. 924, the line of section being taken through the second story of the mill.

General Description.—The house in which this mill is contained consists of an assemblage of plates of sheet-iron, A A A, of a suitable thickness, consolidated and bound together by the cast-iron columns B B B, and by the strong cast-iron girders C C C, situated at such a height as to oppose and neutralize the strain of the principal working parts. It is surmounted by an arched roof D D, formed of plates of corrugated sheet-iron. A wall of masonry E E is erected in the interior, for the purpose of affording a foundation for the bearings of the heavier geering of the mill. The motive power is supplied by a high-pressure steam-engine F, of 12-horse power, its principal working parts are wholly inclosed within a large cast-iron column. By this arrangement great firmness and stability is imparted to the engine, while the space which it occupies is reduced to the smallest possible dimensions. The boilers G G are situated in an adjoining part of the house, and their flues H H are formed, in the usual manner, of brick-work, abutting on the one hand against the wall E, and on the other against the side of the house itself. Thus the engine and boilers occupy nearly the entire half of the lower story of the mill. The whole erection is strengthened and bound together by the cast-iron beams I I I, which pass transversely through the interior of the house, and are supported, in the middle of their length, by the columns J J. On these beams, also, the flooring of the lower and upper flats is disposed.

The fly-wheel K K of the steam-engine, is formed with teeth on the exterior of the rim, thus serving at once to regulate the velocity and to transmit the power of the steam-engine to which they are attached. The spur fly-wheel K K, the diameter of which is 9 feet 3¾ inches, geers with the pinion L of 4 feet 10¾ inches diameter; consequently, the velocity of the crank-shaft is nearly doubled upon the horizontal shaft M M, to which the latter is fixed, and which, by means of the bevel wheels and pinions N N N, gives motion to the stones contained within the stone-cases P P P. The shaft M M has a bearing upon the wall E, close to the back of the pinion L, and one in each of the standards O O O, to which the mechanism necessary for impelling and regulating the action of the stones is attached.

923.

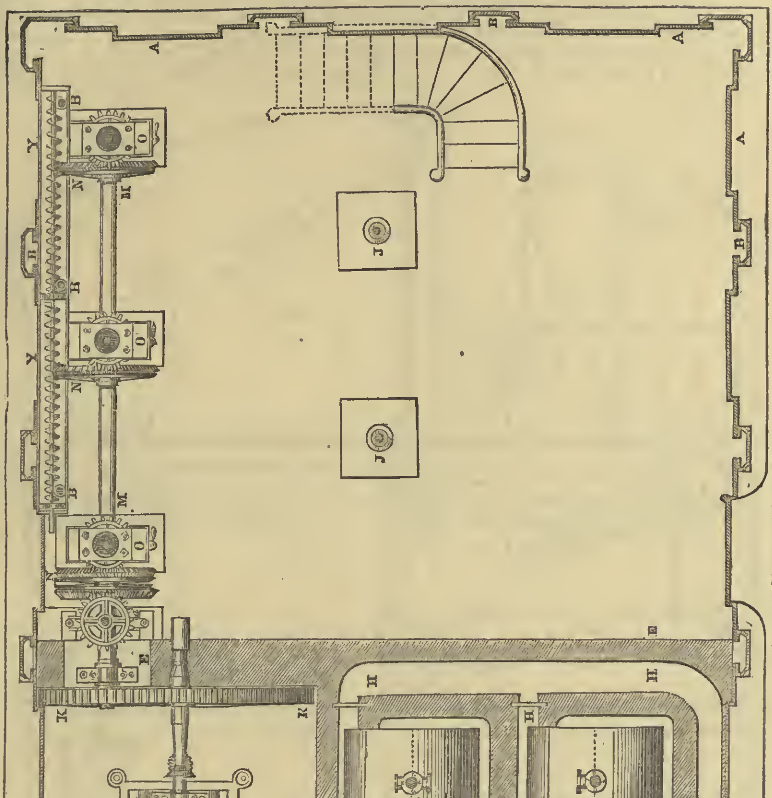


SCALE.—20 feet=3 inches.

The corn to be ground is deposited in the upper floor of the mill in the large garner Q Q, from which it is conducted through the spout R, into the *screening*-machine S S, where it is cleansed of the dust and other extraneous matter which is found more or less combined with it. This machine consists of a species of cylindrical sieve, formed of wire-cloth, and partitioned inside so as to resemble an Archimedean screw. It is mounted upon an axis, and revolves with a considerable velocity in the interior of a close box, in which it is set at an angle with the horizon. The corn enters at its upper extremity, and, after being thoroughly agitated by its passage through the partitions in the interior of the screen, and thereby divested of the greater portion of the refuse with which it was mixed, falls into a spout U, at

its lower end, which conducts it to the *elevator* V; being subjected, in its passage through this spout, to the action of a blast from the fan T, by which the remaining portion of the sand and dust that escapes with the grain is carried off by a passage leading to the exterior of the house. The grain, after being thus cleansed, is caught up by the elevator V, and raised nearly to the summit of the mill, where it is delivered, through an inclined spout X, into the *creeper-box* Y Y, by which it is distributed into the feeding-garners Z Z Z.

924.



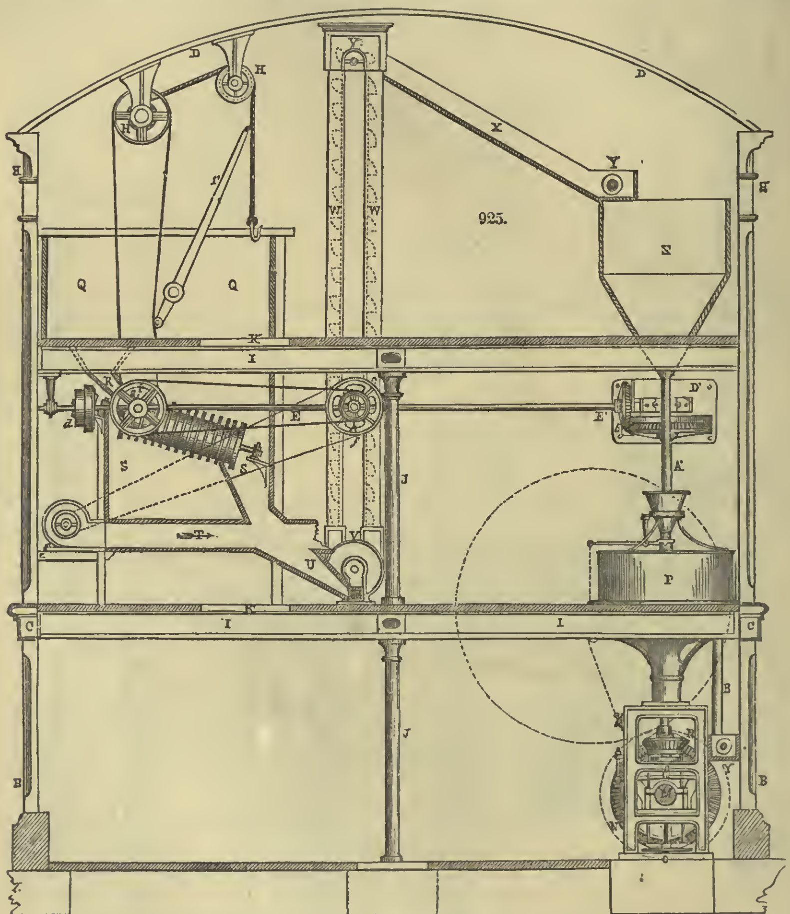
SCALE.—20 feet=3 inches.

The *elevator* consists of a long endless chain of small buckets formed of tin-plate and mounted, at regular distances, upon a leather band passing over two pulleys inclosed within the cast-iron frames V V. The uppermost of these pulleys is driven at a moderate velocity by a belt, and the buckets, passing in succession the opening by which the grain is delivered from the screen, become each charged with a small portion of it; this they convey through the wooden pipes or boxes W W, in which they are inclosed, to the upper extremity of the chain, where they deliver their contents into the spout X.

The contrivance just described is applicable only to the raising of the grain or flour from a lower level to a higher. For horizontal transport, modern millwrights make use of an apparatus called the *creeper*, a long endless screw with a wide pitch and thin threads, inclosed in a wooden box or trough, of dimensions slightly greater than its own diameter. It is made to revolve upon its axis, by means of a belt and pulleys, at a velocity corresponding with that of the elevators, and, being restricted from moving longitudinally, the threads, or rather leaves, of the screw, force the grain introduced at one end

of the trough to the other. The action of the screw in the case of the creeper is identical in its nature with that of the endless screw in giving motion to a worm-wheel.

The corn which is supplied to the garners Z Z Z, falls through the feeding pipes A′ A′ A′, into the hoppers, by which the grinding apparatus is surmounted. After being reduced into flour, it falls through the pipes B′ B′ B′, into the creeper-box Y′ Y′ Y′, by which it is transferred to the elevator V By this elevator it is again raised to the summit of the house, and carried by means of the creeper Y′ to the *dressing*-machine S′. It may be remarked that, besides the great saving in manual labor effected by the use of these contrivances for transporting the flour from one part of the mill to another, they are attended by another very important advantage: by exposing the flour liberally to contact with the air, the heat evolved during the process of grinding is abstracted, and the moisture evaporated; an operation which it is of essential importance that it should undergo previous to the process of dressing



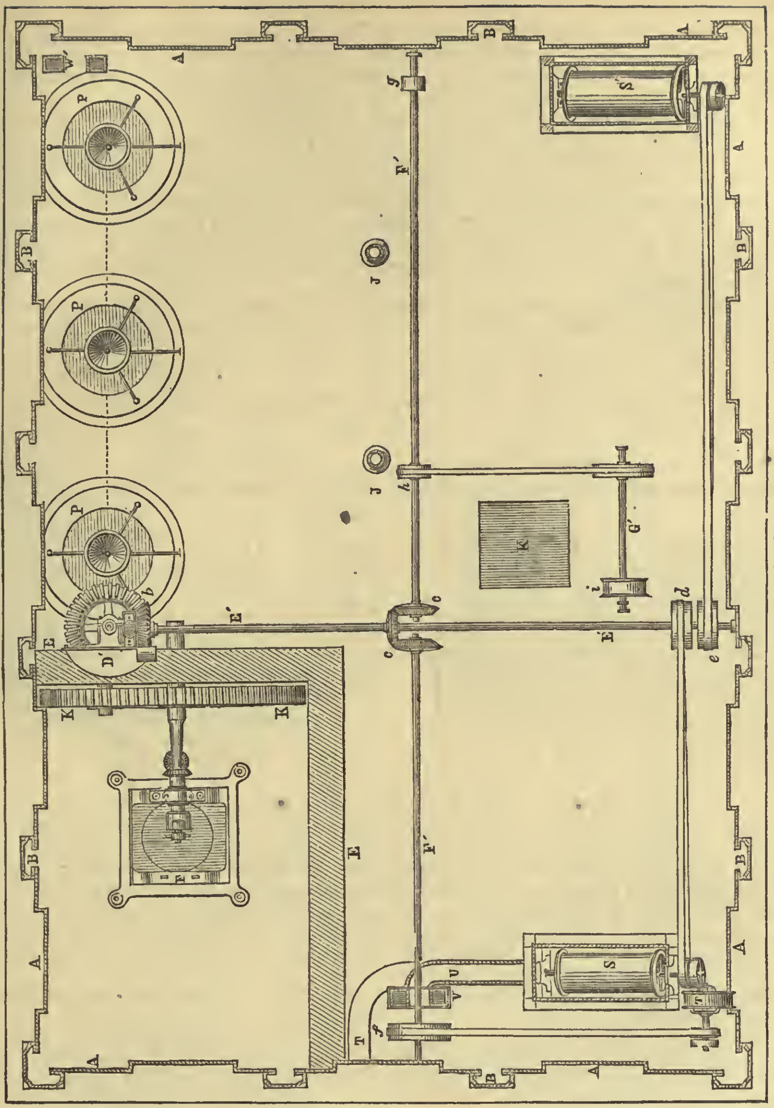
SCALE.—20 feet=3 inches.

This machine, which is very similar in external appearance to the screening-machine already described, consists of a hollow cylinder covered with wire-cloth of different degrees of fineness, the finest being at the end which is most elevated. Within the cylinder, which is stationary, a circular brush revolves, in contact with the wire-cloth of which it is composed. The flour which is fed into the cylinder is, by the motion of the brush, sifted or rubbed through the wire, the finest through the upper end, the second through the next division, and so on, till the bran falls through the end of the cylinder, being too coarse to pass through any of the wires.* The different products thus separated are then stored in sacks, or otherwise disposed of as may be most convenient.

The sack-tackle is very simple, and will be readily understood from the drawing. It consists of a barrel H, provided with a rope of sufficient length to reach to the lower floor of the mill, and fitted to

* On the processes undergone by the corn both previously and subsequently to the grinding, much of the success of the whole operation depends. In place of the wheat-screen, an apparatus called a *sheeling-mill* is employed in some establishments. This consists of a pair of ungrooved millstones working at such a distance apart that the grain is merely rubbed between them, but not cut or broken. From the stones it is received upon an inclined sieve, where the heavier parts of the refuse fall from it, and is then exposed to the blast of a fan which deprives it of the remaining lighter portions. For dressing the *flour*, *bolting*-machines are very generally used either in combination with, or in place of, the dressing-machines described above. These contrivances, however, come more within the province of the *miller* than of the *millwright*.

926.



SCALE.—20 feet=3 inches.

Literal References.

A A A, the sheet-iron sides of the house in which the mill is erected.
B B B, the columns for supporting and strengthening the sides of the house.
C C, horizontal beams passing all round the house at the level of the first floor.
D D, the roof formed of corrugated iron.
E E, a wall of mason-work affording a foundation for the bearings of the driving geering, &c.
F, the steam-engine by which the mill is driven.
G G, the boilers.
H H, the flues and seat of the boilers.
I I I, transverse cast-iron beams for further strengthening the house.
J J, columns for supporting the beams I I I.
K K, the spur fly-wheel of the engine.
L, pinion working into the above, and fast upon
M M, the main horizontal shaft of the mill.
N N N, bevel mortise-wheels and pinions by which the millstone spindles are driven.
O O O, the standards or framework of the grinding machinery.
P P P, the millstone cases.
Q Q, the large garner for uncleaned wheat.
R, spout leading from the garner Q to
S, the screening-machine.
S′, the dressing-machine.
T, a fan attached to the wheat-screen.
U, a spout leading from the wheat-screen to
V W, the first elevator.
X, passage conducting the grain from the first elevator to
Y Y Y, the creeper by which it is distributed into
Z Z Z, the garners for feeding the stones.
A′ A′ A′, the feeding pipes made of tin plate.
B′ B′ B′, the pipes by which the flour is withdrawn from the stone-cases into
Y′ Y′ Y′, the second creeper-box, conducting it to
V′ W the second elevator.
a, bevel wheel and pinion giving motion to
C′ C′, the vertical shaft of the mill.
b, bevel wheel and pinion giving motion to
E′ E′, transverse horizontal shaft.
c c, a set of small bevel geering giving motion to
F′ F′, the longitudinal horizontal shaft.
d, pulley on the transverse shaft for driving the screen.
e, pulley on the transverse shaft for driving the dressing-machine.
f, pulley on the longitudinal shaft for driving the fan.
g, pulley on the longitudinal shaft for driving the elevators and creepers.
h, pulley on the longitudinal shaft for driving the intermediate shaft.
i, pulley on the intermediate shaft for driving the sack-tackle.
G′, the intermediate shaft for conveying motion to
H′ H′, the sack-tackle.
I′, a lever for starting and stopping the sack-tackle.
K′ K′, hatchways by which the sacks are admitted or withdrawn.

revolve in bearings attached to the roof; it receives motion, when required, from a belt connecting the pulley on its axis with a shaft G′ worked by the engine. The length of this belt is so adjusted that the sack-tackle may remain at rest, or be set in motion, according as the long lever I′, (the action of which is to tighten or relax the belt as may be required,) is drawn to the right or left.

The geering by which the subordinate machinery of the mill is driven consists, first, of an upright shaft C′ C′, set in motion by a pair of bevel wheels *a*, from the main horizontal shaft M M. This shaft has its lower bearing in an arched standard embracing the shaft M, and at its upper extremity it is supported by a plummer-block bolted to a double bracket D′, imbedded in the wall E. Its motion is here transferred by means of another pair of bevel wheels *b*, to the horizontal shaft E′, passing transversely across the mill. On this shaft are fixed the pulleys *d* and *e*, which drive the screening and dressing machines; and a set of small bevel wheels *c c*, serve to transmit the motion to the longitudinal shafts F′ F′, by which the elevators, creepers, &c., are propelled; as also the short shaft G′, by which the sack-tackle is driven.

The dimensions of the various wheels, pinions, and pulleys, employed in this mill, and the velocities imparted by them to the machines driven by them respectively, are given in a tabular form below.

Steam-engine F, 12-Horse Power makes 40 Revolutions of Crank-shaft per Minute.

Description of Geering.	Driver.			Driven.		Result. Revolutions per Minute.	
	Diameter. Feet.	In.	Revolutions.	Diameter. Feet.	In.		
Spur Pair K L.......	9	3¾	40	4	10¾	76	on horizontal shaft M.
Bevel Pairs N N N .	3	6	76	1	10	140	on the stones.
Bevel Pair *a*	3	6	76	1	10	140	on upright shaft C′.
Bevel Pair *b*..........	3	0	140	1	9	242	on transverse shaft E′.
Bevel Pairs *c c*.......	1	1½	242	1	11½	140	on longitudinal shafts F′ F′.
Pulley *d*...............	1	6	242	1	0	363	on screening-machine S′.
Pulley *e*	1	6	242	1	0	363	on dressing-machine S′.
Pulley *f*...............	2	0	140	0	6	560	on fan T.
Pulley *g*	0	8	140	2	0	46.6	on elevators and creepers.
Pulley *h*...............	1	0	140	2	0	70	on intermediate shaft G′.
Pulley *i*	1	6	70	2	0	47	on sack-tackle H′.

Details of Corn-Mill.—The figures exhibit the constructive details of the grinding apparatus, and of some of the subordinate machinery employed by Mr. Fairbairn in all his most recently erected mills, whatever may be their extent and the number of stones they contain. The height of the stone floor (or level at which the mill-stones are situated) from the foundation varies slightly in different mills, and the diameter of the driving-shaft must be increased or diminished in proportion to the number of pairs of stones to be driven, and to the distance of each individual pair from the prime mover. The only deviations from the form and dimensions here given, are, in the former case, to alter the length of that part of the framing called the cone B B, and in the latter to increase or diminish the diameter of the bearings in the plummer-block G G.

Enumeration of the Plates.—Fig. 927 is a front elevation of the grinding machinery, exhibiting the external appearance of the whole.

Fig. 928 is a general section taken on a vertical plane at right angles to that of the elevation, Fig. 929. In this view the millstones and the whole grinding apparatus are shown in combination.

Fig. 929 represents a plan of the cone, showing the number and disposition of the adjusting screws of the lower stone.

Fig. 930, an enlarged external view of the feeding tube; Fig. 931, an enlarged elevation, and Fig. 932, a plan of the lever for regulating the supply of grain admitted to the stones.

Fig. 933, a plan of the ring forming the top of the tripod on which the feeding hopper is supported.

Fig. 934, a plan of the ring by which the adjusting wedges of the upper bearing of the mill-spindle are regulated.

Fig. 935, an enlarged view of the mill-spindle.

Fig. 936, an external elevation; Fig. 937, a vertical section; and Fig. 938, a plan of the *Ryne*, or crosshead by which the upper stone is connected to the spindle, and the grain supplied to the stones.

Fig. 939 is a face view, and Fig. 940, a plan of the sockets in which the ryne works.

Fig. 941 is a plan of one of the millstones, showing the disposition and mode of drawing the grooves on its surface.

Fig. 942 is a plan of the cast-iron socket inserted into the lower stone, and forming the upper bearing of the mill-spindle; Fig. 943, an edge view, and Fig. 944, a front view of the brass bushes fitted into this socket.

Fig. 945, a face view, and Fig. 946, an edge view of one of the wedges by which the brasses of the mill-spindle are adjusted.

Fig. 947 is a sectional plan of the principal standard or frame of the mill, showing the mode of adjusting the lower end of the mill-spindle. The line of section is taken on the dotted line 1—2 in the general section, Fig. 928.

Fig. 948 is a sectional plan of the standard taken on the line 3—4, Fig. 928, and exhibiting the mechanism for disengaging the driving pinion when necessary.

Fig. 949 is a partial section of the standard and attached mechanism. This section is taken on a plane corresponding with that of Fig. 927.

Fig. 950 is a side elevation, and Fig. 951, a plan of the plummer-block of the driving-shaft.

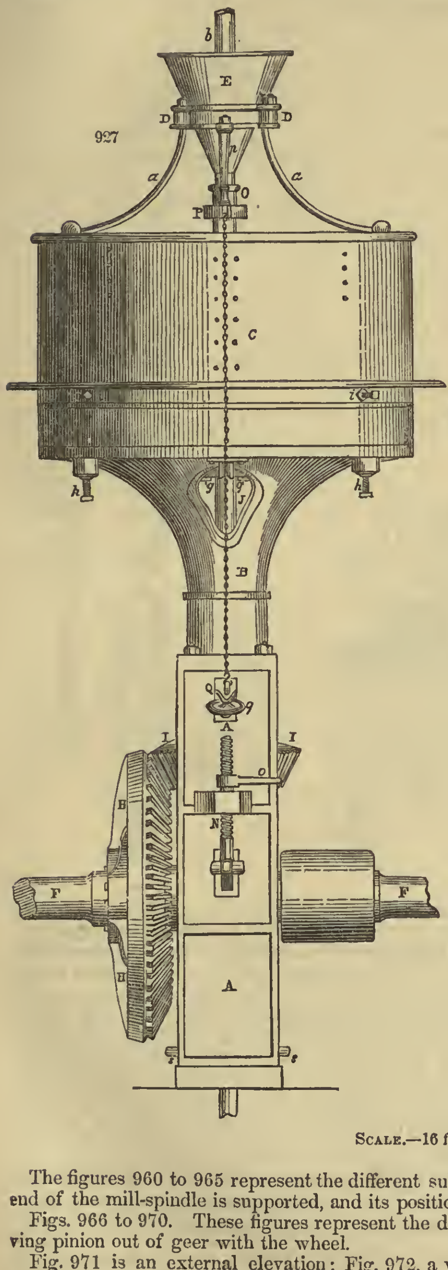
Fig. 952 is an external elevation, and Fig. 953, a plan of the driving pinion of the mill.

Fig. 954 is a side view, and Fig. 955, a plan of the lever for adjusting the lever of the upper stone.

Fig. 956 is an edge view; Fig. 957, a front view of the screw and nut by which the adjusting lever is regulated.

Fig. 958 is an edge view; Fig. 959 a plan of the key used for working the above adjusting apparatus.

927



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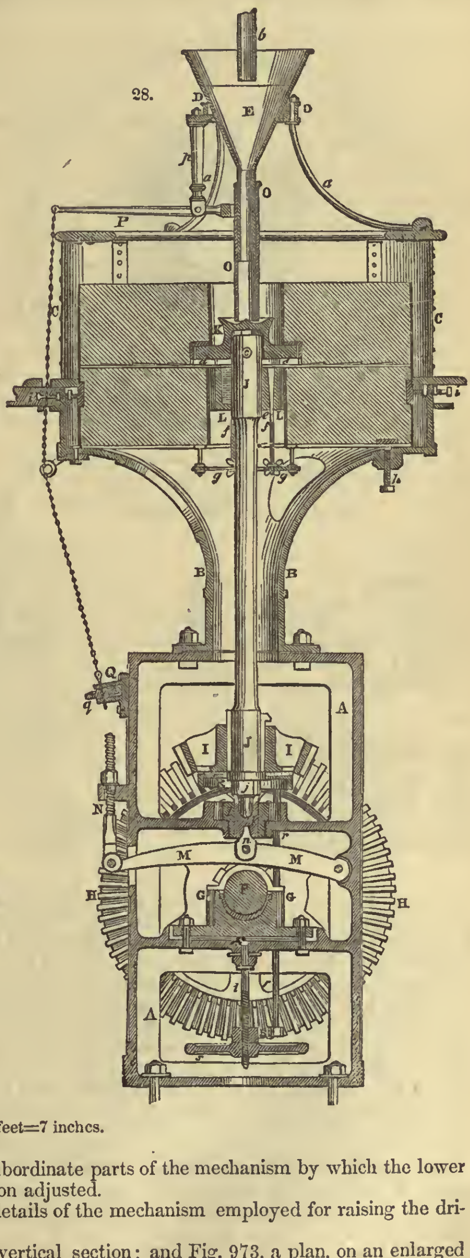


SCALE.—16 feet=7 inches.

The figures 960 to 965 represent the different subordinate parts of the mechanism by which the lower end of the mill-spindle is supported, and its position adjusted.

Figs. 966 to 970. These figures represent the details of the mechanism employed for raising the driving pinion out of geer with the wheel.

Fig. 971 is an external elevation; Fig. 972, a vertical section; and Fig. 973, a plan, on an enlarged scale, of the small apparatus used for regulating the feeding of the mills.

Figs. 974 to 977. These figures give a representation, on a large scale, of the various adjusting

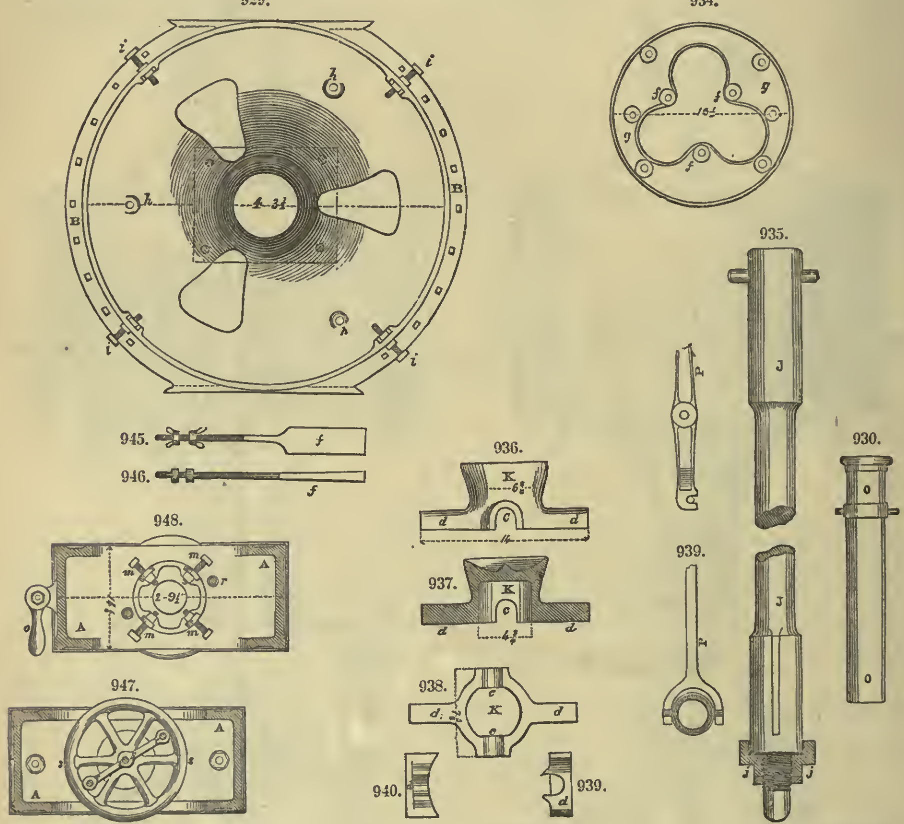
screws required in this grinding machinery: the first two are for adjusting the lower end of the mill-spindle; the third for centering, and the fourth for levelling the lower or fixed stone.

Figs. 978 to 982. These figures represent general and detailed views of a species of small portable crane or jack, employed for the purpose of raising and replacing the upper millstones when they require to be redressed.

Fig. 983 is a side elevation, and 984, an edge view of the lower elevator framing.

Figs. 985 to 990. These figures give minute representations of the construction of the creeper. Figs. 985 and 986 are a section and external view combined to show the mode of junction of the different lengths; Fig. 987 is a transverse section of the creeper-box; Fig. 988, a plan of the plug or connecting block; Fig. 989, a view of the stud or journal which terminates the range, and Fig. 990, of that which commences it, and on which the driving-pulley is keyed.

929. 934.



935. 930. 945. 946. 936. 948. 937. 939. 938. 947. 940. 939.

General Description. The Framing.—A strong cast-iron standard or framing A A, securely bolted to a stone foundation by two holding-down bolts, incloses the principal part of the driving and adjusting geering for each pair of stones. It is made somewhat in the form of an oblong box, and is traversed by two horizontal diaphragms or partitions, cast of a piece with it, the upper one for sustaining the lower bearings of the mill-spindle, and the under, the plummer-block of the driving-shaft. It is surmounted by a large bell-shaped casting B B, called the *Cone*, firmly bolted, by a flange at its lower end, to the standard, while the upper extremity is expanded, and terminates in a cylinder, of a diameter somewhat greater than that of the millstones, the lower of which rests, and is secured, within it. Two straight and broad flanges are cast at the opposite sides of the cylindrical part, for the purpose of bolting the cone to the beams of the mill, or to the same parts of the framing of the contiguous pairs of stones, while another circular flange passes all round, for sustaining the flooring. Three large openings are left in the upper part of the cone to give access to the interior, and it is provided with suitable arrangements for the reception of the several adjusting screws required for the setting of the lower stone.

The Stone-Case and Feeding Hopper.—Above the cone, and of the same diameter with the cylindrical part of it, is placed the stone-case C, which surrounds the upper stone, and serves to confine the flour which is the result of the grinding. This is simply a cylinder of thin sheet-iron, resting upon the stone floor, and having affixed to the top of it a ring of wood, on which the tripod for supporting the feeding apparatus is set. This cover is made open in order to admit the air freely between and around the stones during the process of grinding. A cast-iron ring D, supported by three malleable-iron legs *a a a*, forms a sort of tripod in which is placed the hopper E, which receives the grain from the garners above.

through the feeding pipe *b*, and supplies it to the stones by means of the feeding apparatus to be hereafter described. A piece of coarse wire gauze is placed in the hopper E to intercept any foreign body that may descend with the grain.

The Driving Geer.—The driving shaft F is part of the line of horizontal shafting which is common to the whole range, and which receives its motion from the prime mover, generally through the intervention of a single wheel and pinion. The velocity of this line of shafting is usually from 70 to 80 revolutions per minute, with stones of the diameter of those in our examples. The different lengths of which it is composed are connected together by couplings of the same description as that described and represented at Figs. 950 and 951. The shaft F revolves in brass bearings, fitted into a plummer-block G, bolted to a sole formed, as before noticed, in the standard A. The strain of the shaft being entirely in a downward direction, this plummer-block requires no cover, the journal being simply protected from injury by a slight brass cap.

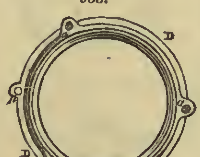
A large bevel mortise-wheel H, working into the pinion I, on the mill-spindle, serves to transmit the motion of the shaft F to the latter. The pinion is not fixed immoveably upon the spindle, but is capable of sliding vertically upon it by means of a sunk feather.

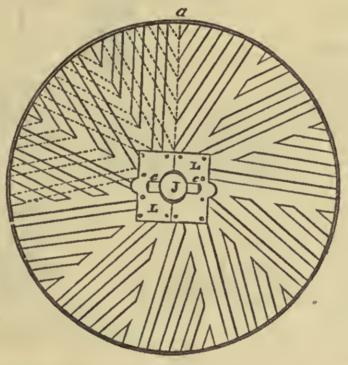
The Mill-Spindle and its Appendages.—The mill-spindle J J is made of the best forged-iron, accurately turned over its entire length, and rises perpendicularly through the standard A, the cone B, and the lower millstone. It is attached to the upper, or running stone by means of a cast-iron piece K, called the *Ryne*, which combines this function with that of regulating and delivering the supply of grain to the stones. It is in the form given to this very important part that Mr. Fairbairn's most recent improvement in grinding machinery consists. It will be observed by the drawings, Figs. 936 to 940, that it forms a species of universal joint; the small steel crosshead *c c* on the top of the mill-spindle fitting into corresponding bearings in the ryne, while the projecting tails *d d*, cast upon it at right angles to the former, work in similar bearings formed of small cast-iron pieces sunk into the stone. By this arrangement it will be observed, that the connection between the mill-spindle and the upper stone is complete, while at the same time it admits of the free and unconstrained action of the latter against the grinding surface of the lower stone.

The lower, or fixed stone is perforated by a large square hole in its centre, into which the cast-iron block L, Fig. 942, is firmly fixed by slips of wood and wedges. Into this block are fitted the three brass bushes *e e e*, which form the upper bearing of the mill-spindle. These are adjusted by means of the wedges *f f f*, the screwed tails of which pass downwards through the cast-iron ring *g*, and are regulated by thumb-screws on each side of it. The large openings in the cone, before alluded to, afford access for the working of these screws. Small semicircular chambers are formed in the socket L, between each bush, and filled with hemp and tallow, for the lubrication of the mill-spindle; and the whole is carefully protected from dust by slips of sheet-iron screwed over it, Fig. 941.

941.

933.





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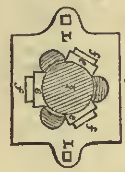

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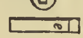

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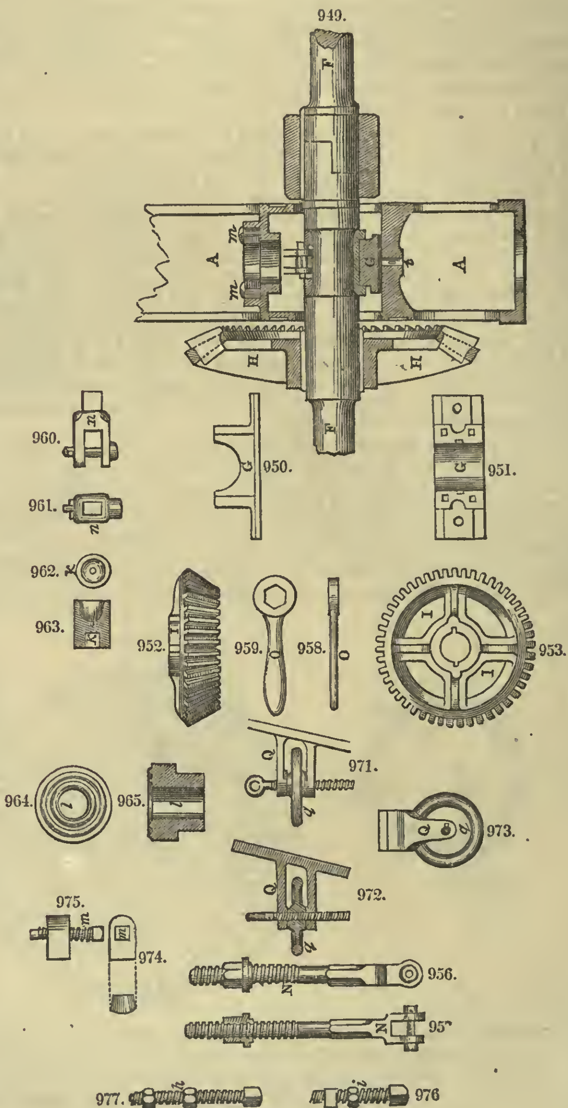
The Millstones.—The diameter of the millstones most in use at the present day is 4 feet, and their thickness about 12 inches; one-half of this thickness is composed of French burr, a very hard, though porous mineral, of a silicious nature; the other half is made up of plaster of Paris. In consequence of the difficulty of obtaining sufficiently large masses of the French stone, it is usual to construct the millstones in segments, which are cemented together, and the whole firmly bound by iron hoops passing round the circumference. The lower stone is, in the first instance, carefully dressed into a perfectly flat, plane surface, but the upper one is made slightly hollow for a small distance from the central aperture, so as to allow the grain to be freely admitted between the stones. Being thus prepared, grooves are then cut on the rubbing surfaces of both, in the manner indicated in Fig. 941. The circumference of the stone is first divided into eleven equal parts;* lines are drawn from each division to the centre; these radii determine the limits of the grooves in each compartment. A chord $b' c'$ is then drawn, joining the bounding radii of any two compartments; this chord is, of course, bisected by the intermediate radius J a', in d'. Divide the line $d' c'$ into four equal parts in the points $e' f' g'$; and from these points mark off, on the line $d' c'$, distances equal to the width of the groove to be cut; then draw through all these

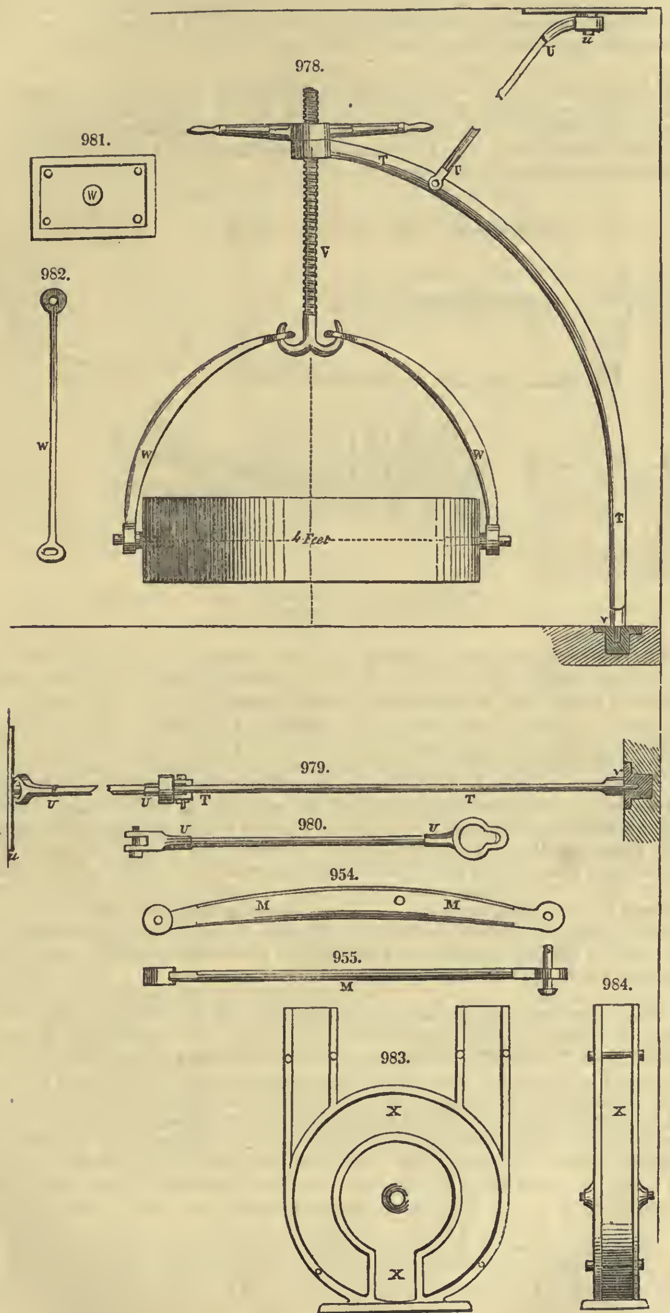
* The number of channels formed in the stones, and consequently the number of compartments, or *quarters* into which they are primarily divided, are varied by different millers, but the mode of drawing the lines, as here given, is applicable in all cases.

Literal References.

A A, the standard or lower framing of the grinding machinery.
B B, the cone or upper framing.
C, the stone-case, of sheet-iron.
D, a cast-iron ring forming the support of the feeding hopper, and carried upon
a a a, three malleable-iron legs, resting upon the top of the stone-case.
E, the feeding hopper.
b, a pipe made of thin sheet-iron, supplying grain to the feeding hopper from the garners above.
F, the main driving-shaft.
G, the plummer-block in which the shaft F revolves.
H the bevel mortise-wheel, communicating the motion of the shaft F, to
I, the pinion of the mill-spindle.
J, the mill-spindle.
K, the ryne of cast-iron, by which the mill-spindle is connected with the upper stone, and the feeding is regulated.
c d, the bearings of the universal joint formed by the ryne.
L, the cast-iron socket for the upper bearings of the mill-spindle.
e f, bushes and wedges for adjusting the upper bearing of the mill-spindle.
g, a thin cast-iron plate, by means of which the wedges *f f* are tightened and retained in their places.
h h h, pinching-screws for adjusting the level of, and
i i i, pinching-screws for centering the lower mill-stone.
j, a large brass nut, with jam-nut, for retaining the pinion I constantly in its proper position with regard to the driving wheel.
k, the footstep of the mill-spindle, of brass or gun-metal.
l, cast-iron socket for the footstep *k*.
m m, pinching-screws for adjusting the socket *l*.
n, the saddle or link connecting the footstep *k* with
M, the great lever for supporting and regulating the position of the mill-spindle.
N, the screwed rod for working the lever M.
o, cast-iron screw-key for the same.
O, the moveable feeding-pipe of cast-iron.
P, lever for regulating the position of the feeding-pipe O.
p, small column forming the centre of motion of the lever P.
Q *q*, apparatus for working the feeding mechanism.
R, a cast-iron ring for raising the driving pinion out of geer with the wheel.
S, a cast-iron crosshead, being part of the same apparatus.
r r, upright rods connecting the cross head S, with the ring R.
s s, a hand-wheel for working the disengaging geer.
t, a screw working through the eye of the hand-wheel *s*.
T U V W, the several parts of which the stone lifting machine is composed.
u v, the centres of motion on which it rotates.
X, the lower elevator-frame, of cast-iron.
Y Y, the creeper, of cast-iron.
w x, blocks and studs for connecting the adjacent lengths of the creeper.
y, the brackets in which it revolves.
Z Z, the creeper-box, of wood.



points of division lines parallel to the radius J a', terminating them in the radius J c'. These are the outlines of the grooves, which are then to be cut into the stone, perpendicularly on one side and obliquely on the other, so that each furrow shall have a sharp edge. The direction of the grooves being the same in both upper and lower stones as they lie on their backs in the position proper for being cut,



It is obvious that when the former is reversed and set in motion, their sharp edges will meet each other after the manner of a pair of scissors, (as partially shown by the dotted lines in Fig. 941,) and thus grind the corn more effectually when it is subjected to the action of the unbroken surfaces between the channels.

Adjustment of Lower Stone.—It is of the most essential importance to the proper working of any pair of stones, that the grinding surface of the lower stone should be perfectly level, and that its centre should be exactly perpendicular above that of the lower bearing of the mill-spindle. To secure the former of these conditions, three pinching-screws *h h h*, are fitted into the cone, (that number being greatly preferable to four in adjusting the *level* of any surface;) and, bearing against small slips of iron sunk into the stone, it can be raised or depressed by them to any required extent. The *centering* of the stone is effected by means of *four* pinching-screws *i i i i*, acting horizontally upon it. To secure it against deviating from the truth after having been properly adjusted, all these screws are provided with jam-nuts.

Adjustment of Mill-Spindle.—The lower bearing or footstep of the spindle J is also made capable of nice adjustment, both horizontally and vertically. The former is necessary in order to ensure the accurate working of the driving wheel and pinion, and the latter to regulate the pressure of the upper upon the lower stone, and to compensate for the changes produced upon both by the frequent dressings which their grinding surfaces have to undergo.

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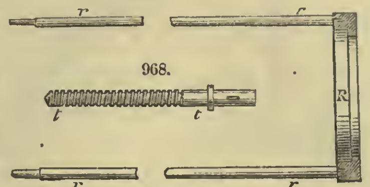

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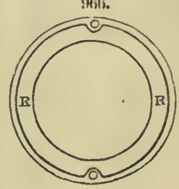

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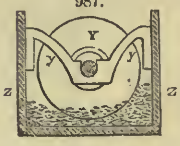

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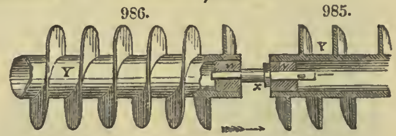

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The footstep *k*, which is of gun-metal, is turned and fitted accurately into a cast-iron socket *l*, resting on the upper diaphragm of the standard A; the hole into which it is inserted and the annular recess by which it is surrounded being made of somewhat greater diameter than the corresponding parts of the socket itself. Its exact position is determined and secured by the four lateral pinching-screws *m m*, passing through the ring and working in nuts fitted into recesses cast upon its interior surface. (See Figs. 947 and 975.) The footstep *k* is not fixed immoveably into the socket *l*, but is capable of sliding vertically in it. Its proper position, in this direction, is regulated by means of a strong malleable-iron lever M, having its centre of motion in the back of the standard A, while its opposite end projects through a slot, and is raised or depressed by means of a screwed rod N, joined to it and passing through a projecting shelf cast upon the front of the standard. A small link or *saddle n*, serves to connect the lever with the footstep *k;* the saddle being provided with a *square* tail which is inserted into a similar recess in the under side of the footstep; by which means the latter is prevented from turning in its socket. Thus it will be seen that the entire weight of the upper stone and mill-spindle rests upon the lever M, and that the miller is enabled to vary at pleasure the pressure upon the grain between the stones, and consequently, the degree of fineness of the flour produced, by simply turning the nut of the screw N by means of the key *o*.

The Feeding Apparatus.—The supply of grain admitted between the stones is regulated by means of a cast-iron pipe O, open at both ends, the lower end being brought into close proximity with the ryne, while the upper part incloses the pipe in which the feeding hopper E terminates. It is suspended by means of a cast-iron lever P, which has its fulcrum in the small column *p*, depending from the tripod D. A small chain attached to the end of the lever, and passing over a friction-pulley at the bottom of the stone-case, serves to connect this feeding apparatus with an ingenious little piece of mechanism Q attached to the standard, by which the miller is enabled to regulate the supply with the greatest nicety.

This contrivance (which is represented on a large scale at Fig. 971) consists of a small hand-wheel *q*, working between the cheeks of a double bracket bolted to the standard A. A small screwed pin forms the axis of this wheel; it passes freely through the cheeks of the bracket, but is screwed into the eye of the hand-wheel, and is prevented from turning with it by means of a feather inserted into the former and fitting into a groove cut throughout the entire length of the pin, to the upper end of which the chain is attached. By this arrangement it is obvious that by turning the hand-wheel *q* to the right or left the small pin will be raised or depressed, and, through the intervening mechanism, the size of the opening between the mouth of the feeding-pipe O and the ryne will be increased or diminished.

The form given to the upper surface of the ryne may be looked upon as the highest point of perfection to which this important part of grinding machinery can be carried. We have been at great pains to give an accurate representation of it in our various views, (see Figs. 928, 936, 937, 938, 939, and 940.) The principle by which its form is determined is, that the centrifugal force of the running stone shall be employed in the most effectual manner to distribute the corn equally over every point of its surface, while at the same time, the supply admitted shall be susceptible of the nicest possible adjustment.

The Disengaging Apparatus.—The driving pinion I is fitted upon the mill-spindle so as to be capable of sliding up and down upon a sunk feather. When fully in geer with the wheel H, it rests upon a collar formed on the upper surface of a large brass nut *j*, by which the miller is enabled to keep the pinion invariably in its proper position with regard to the wheel, independently of the position of the spindle, which, as we have before had occasion to remark, requires to be slightly lowered every time the stones are dressed. When properly adjusted, the pinion is secured to the spindle by a tapered key.

It is, however, necessary to throw each pair of stones, periodically, out of geer with the general range, to admit of their being dressed, &c. For this purpose the tapered key is removed and the pinion raised out of contact with the teeth of its driving-wheel by means of a species of small jack or lifting apparatus attached to the standard, the component parts of which we shall now briefly enumerate. A cast-iron ring R, supported upon two upright rods *r r*, is brought into contact with the under surface of the pinion by turning the hand-wheel *s*, which is screwed upon its axis *t*, and carries with it in its ascent, the cross-head S, into the ends of which the lower extremities of the rods *r r* are inserted. The screw *t* is fixed into a socket cast upon the under surface of the lower diaphragm of the standard, and the connecting rods *r r* pass through holes formed for their reception in both diaphragms; being set in a diagonal direction in order to clear the lever M, and other important parts of the machinery.

On turning the hand-wheel in the contrary direction, the weight of the pinion again brings it into its working position.

The Stone-lifting Machine.—Fig. 978 is a representation of a portable lifting apparatus, for raising the upper stones from their beds and depositing them on the floor of the mill, when they require to undergo the process of dressing. It consists of a strong malleable-iron arm T T, bent into a form nearly approaching to a quadrant; the lower end works in a cast-iron step *v*, inserted into the stone floor, while its upper extremity is supported by a strong rod U, fitted to rotate upon a stud *u*, fixed into a cast-iron plate (Fig. 981) bolted to the beams which support the floor above. The fixed centres *u* and *v* are so situated that the machine shall command two contiguous pairs of stones, and the end of the rod U is made of such a form as to admit of its being easily disengaged from the stud; when the entire machine may be removed. A strong screw V, passing through the arm T, and worked by means of a nut formed into a double handle, carries at its lower end the two connecting links W W, which are attached to the stone by two studs temporarily inserted into it at points diametrically opposite. The links W W are bent so as to admit of the stone being inverted while it is suspended in the lifting machine. The running stone is retained in its place in the mill simply by its own weight; it is, therefore, only necessary to raise it out of its bearings when the grinding surfaces require examination or repair.

The Elevators and Creepers.—Figs. 983 and 984 are a representation of the form given to the lower elevator-frame; the nature and construction of this machine having been fully noticed in our previous description, it is not necessary further to advert to them. The creeper, however, Fig. 985, is an object of greater interest. The material employed is cast-iron; the creeper is made in six feet lengths; each length being in the form of a tube, 3½ inches in diameter, and about ⅜ of an inch thick, with broad leaves or threads cast round it in the form of an Archimedean screw. The thickness of the threads does not exceed $\frac{3}{16}$ of an inch at the outer extremity.

The different lengths of which the entire creeper is composed, are joined together by short malleable-iron studs *x x*, forming also the journals on which it revolves. These are made with square tails fitted into similar holes formed in the centre of the small cylindrical blocks *w w*, which are carefully turned on their exterior surfaces, and driven into the open ends of the pipes Y Y, previously bored to the same diameter. This construction at once insures a strictly rectilinear axis for the entire range, whatever may be its length. Minor details will be understood by a simple reference to the figures. The arrow indicates the direction in which a creeper, constructed in the manner shown in the general view, would propel the grain.

CORN-MILLS of MM. Cartier and Armengaud, Sen. The corn-mills after the American system, have undergone useful and important alterations since their introduction into France, though but recently introduced. This system was followed but slowly from the difference in its operation from that of the French mills. The owners of the old mills were satisfied with the work done, with little care on their part respecting improvements.

It is only since the importation of the American process that this industry has received a new impulse, and that a new era has commenced; for this system has driven before it the routine with which the old system was encumbered. The new system was already well known all over England when it made its appearance in France, where it received great amelioration.

The old method required a large number of hands, while the new supplies their place, or rather their work, by the ingenious motions imparted to the different parts of the mills by the machinery.

The construction of the different pieces, as well as their disposition, are not always similar; the mill of Cartier and Armengaud appears to us the most worthy of notice; there are ten couples of millstones set in motion by the same hydraulic wheel.

Explanation of the Figures.

Fig. 991, front exterior view of the mechanism of the mill, (first system.)

Fig. 992, a vertical section of the axis on the line 1—2, of the plan, Fig. 997, (second system.)

Fig. 993, a vertical section, perpendicular to the preceding, on the line 3—4, Fig. 996.

Fig. 994, a section through the axis of a stone and of a pillar, on the line 5—6, Fig. 995.

Fig. 995, a horizontal section above the platform, parallel to the line 7—8, of the preceding Fig.

Fig. 996, the general plan of the first system, showing the disposition of the millstones. This plan exhibits the work at different heights, in order to bring under observation the covers of the stones, the inferior stones and their flooring, the triangles and frames which contain them.

Fig. 997. the general plan of the second system, with disposition altogether similar to the first. The

horizontal sections are here represented at different depths underneath the frame-work of the stones, exhibiting the pinions of the stones and the horizontal wheel commanding them, the pedestals into which are inserted the ends of the axles of the stones, the pillars and circular platform which give support to the whole.

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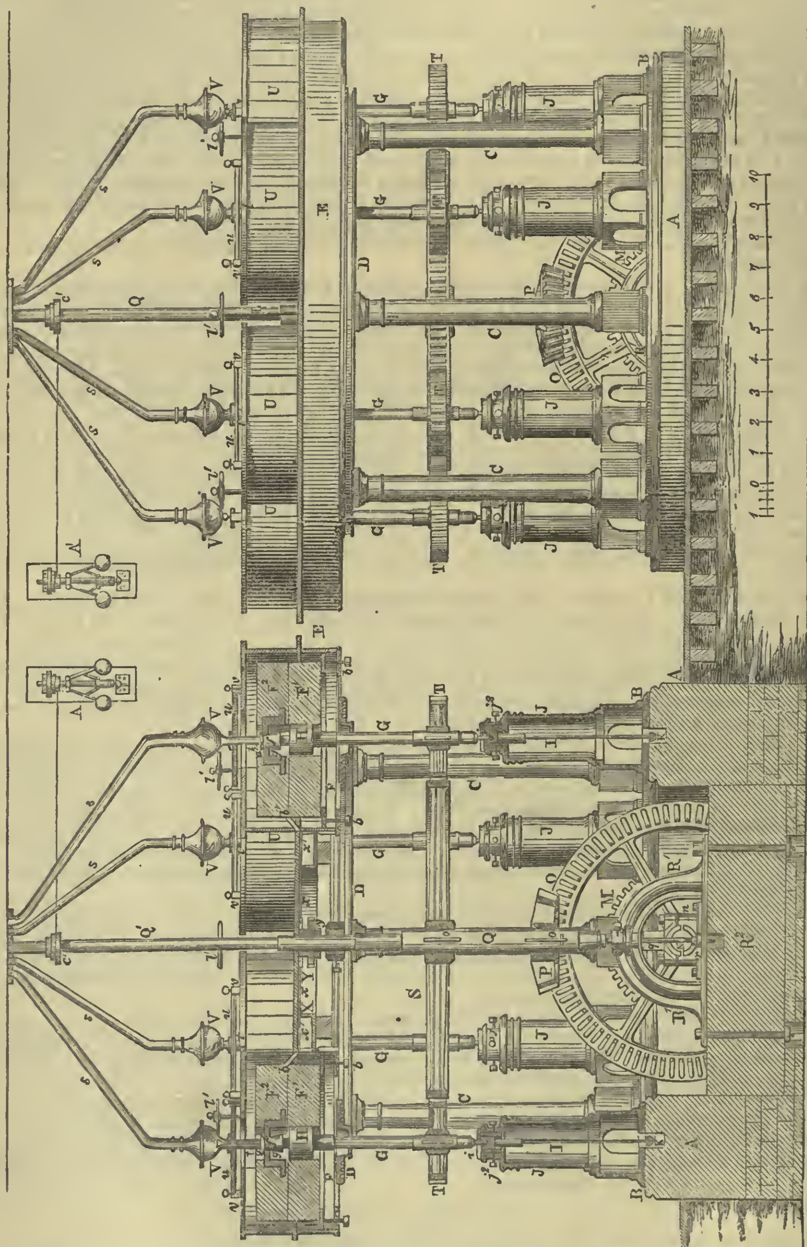

SCALE.—66 feet=13 inches.

Figs. 998 and 999, a vertical section and plan of the iron axle of a mill-stone.
Figs. 1000 and 1001, a vertical section and plan of the superior portion of one of the cast-iron pedestals.
Fig. 1002, a steel socket on which the iron axle of the mill turns.

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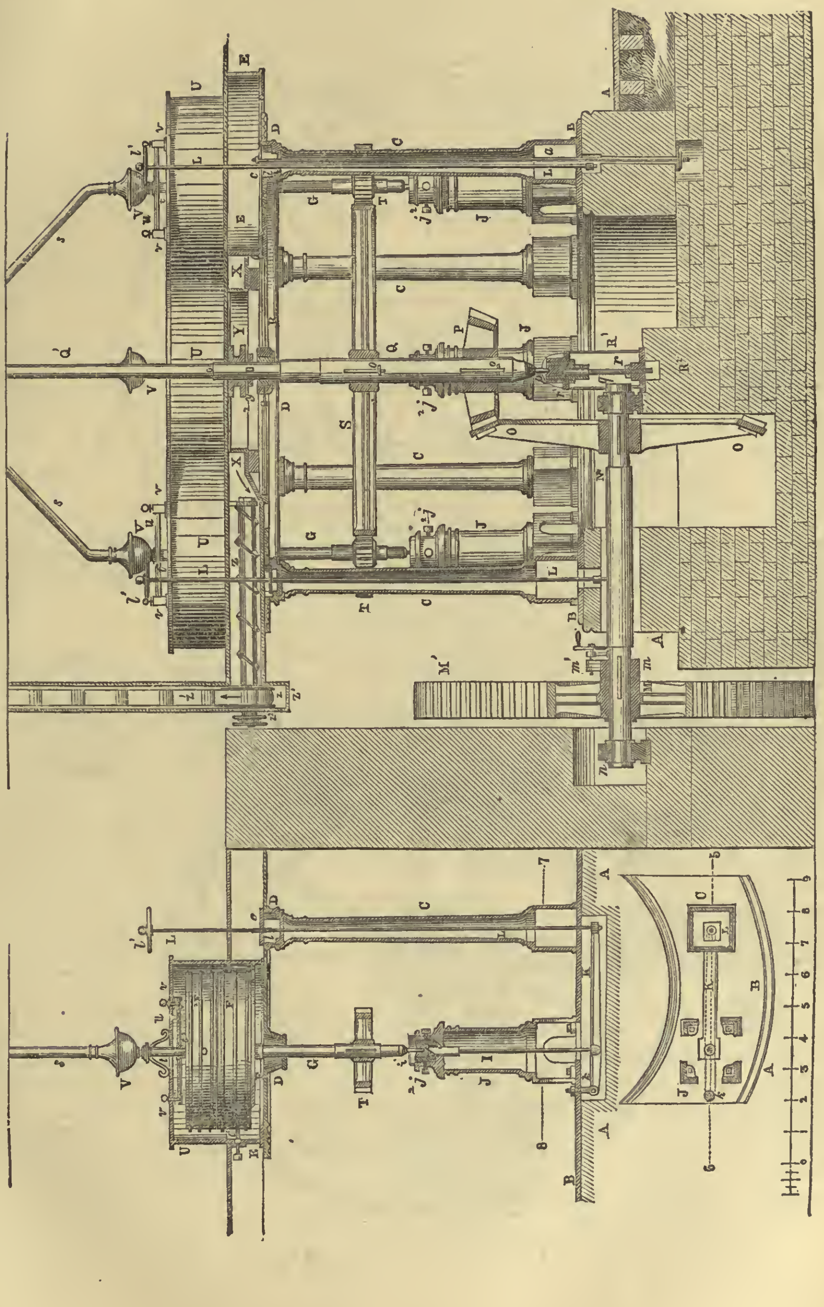
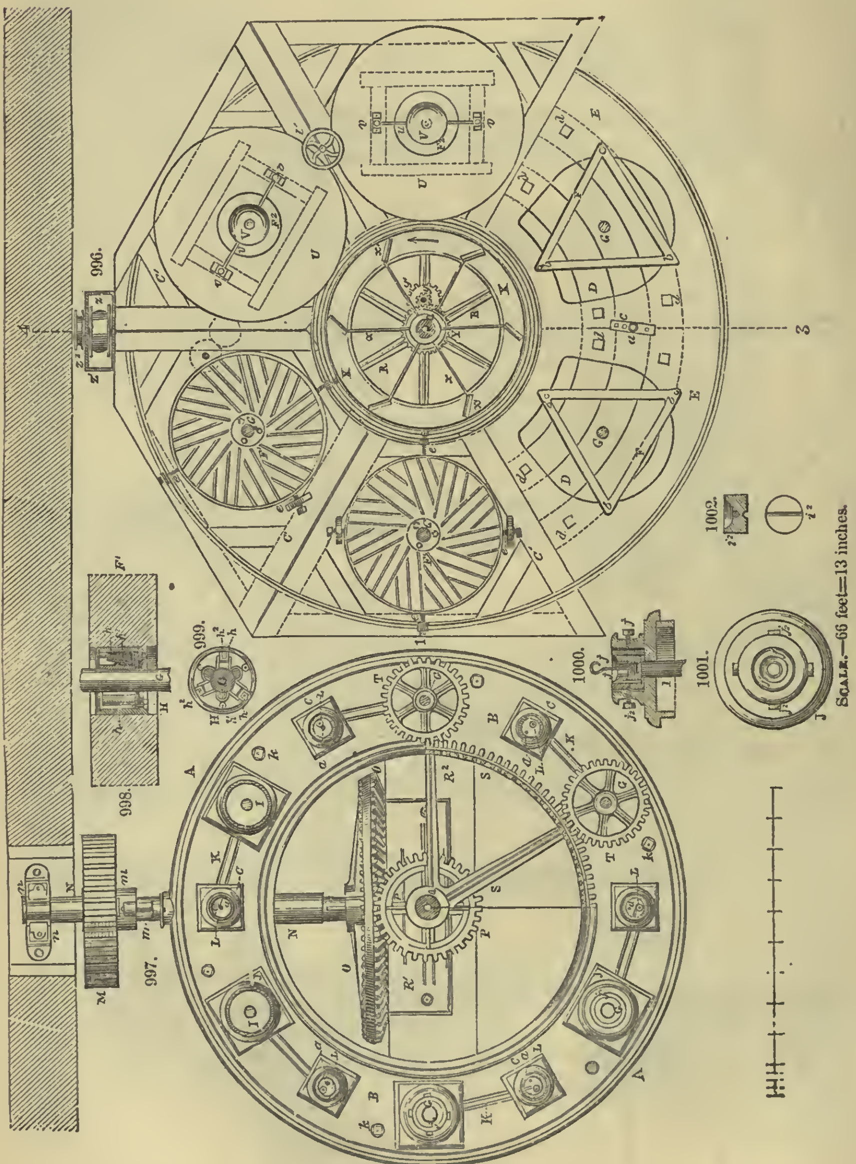


SCALE.—66 feet=13 inches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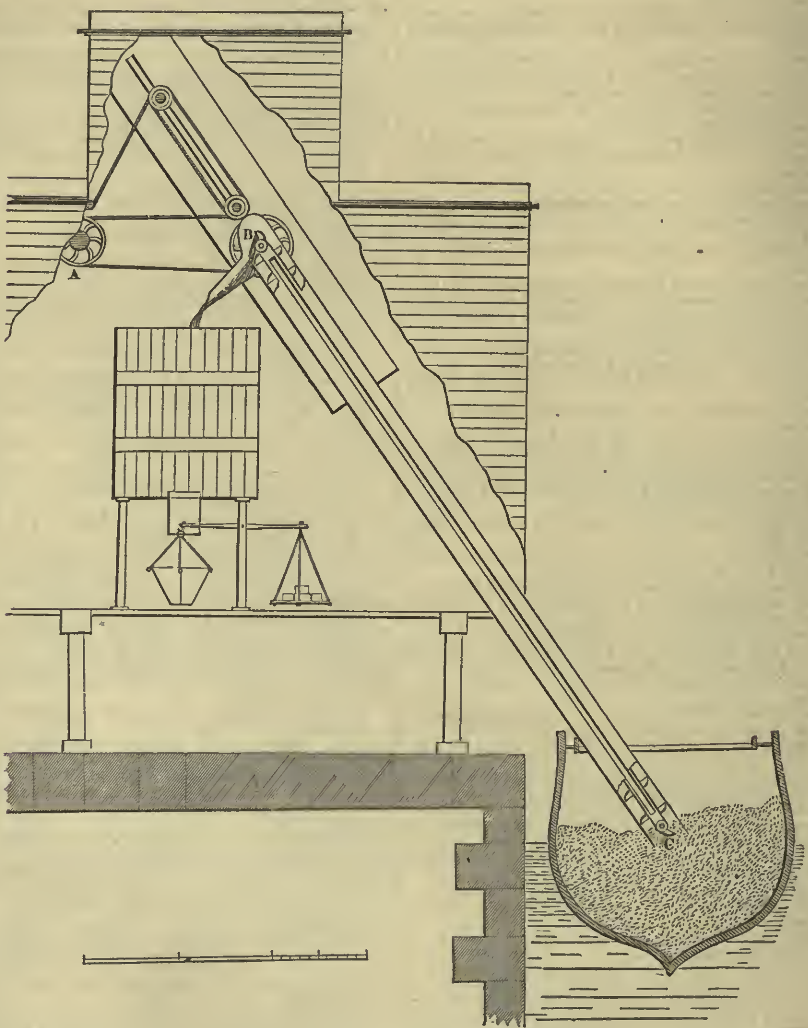
SCALE.—66 feet=13 inches.

References to Figs. from 991 *to* 1002.

A, circular stone-work, on which the whole system, composed of six couple of stones rest.
B, the circular platform of cast-iron placed on the stone frame-work.
C, six iron pillars of equal height, fixed to the platform by pins which penetrate them their whole length, and also the stone circle.
D, the cast-iron rim, made of one solid piece; the pins of the pillars also penetrate it, thus fixing them firmly to this rim.
a, six long pins traversing the rim, the pillars, the platform, and all the thickness of the stone-work, thus firmly binding the different parts to each other.
E, six cast-iron cases resting on the cornice, in which the lower millstone is contained.
F, cast-iron triangles, placed at the bottom of the cases, in order to give the position required to the under millstones.
b, screws adapted to the triangles, to govern them.
c, iron plate fixed to the rim, into which the resting-rods L are screwed, receiving the pressure exercised by the nuts of the pins *a*.
d, Fig. 996, square-headed screws binding the cases to the rim.
e, round-headed screws holding the immoveable stones.
F′, immoveable stones, of the diameter of 4·26 feet, iron-bound, and borne upon the triangles F; they are furrowed, as indicated in Fig. 996.
F², running wheel, of the same diameter, revolving above the former. They are also 4·26 feet diameter.
G, vertical axles in cast-iron of the running wheels moving them.
f, cast-iron bushing of a conical shape, adapted to the axle G.
g, cast-iron chuck, having two arms contained within *f*, attached by their extremities to the moveable stone, and held in equilibrio upon steel disks, adapted to the axle of the stones, and having a spherical part, which serves as a pivot to the centre of the chuck.
H, cast-iron cylinder fixed to the nether millstones, Figs. 997 and 998.
h, flat pillow in bronze, contained within H, and bearing against the iron axles of the millstones.
h′, braces; they are of cast-iron, placed in the bottom of the drums, and fixed to them; they serve to keep the pillows firmly fixed.
*h*², cast-iron wedges, pressing the pillows against each other.
i′, steel pins, adapted to the inferior portion of the iron axles connected with the stones.
*i*², Fig. 1002, steel socket, in which the ends of the axle *i*′ rest.
I, vertical rods of iron, by which the axles and consequently the millstones are raised.
J, cast-iron pedestals, mostly round, and pinned by their base to the circular platform.
j, cast-iron sockets, placed in the superior part of the pedestals; their shape is seen in Fig. 1000.
j′, brass socket made to be adapted to the cups *j*; they rest upon the summit of the vertical rods I, to rise and descend with them, and receive the sockets *i*².
*j*², a screw to set the sockets in the centre, and consequently the axles of the millstones.
K, cast-iron balance-beam, connected with the resting-rods.
k, iron bolts, serving to rest one end of the beam K; a nut maintains each of the bolts fixed to the platform.
L, long rod, connected to the beam K, but allowed to revolve round its own axis.
l, a portion of L, of a greater diameter than the rest, and tapped at the height of the rim.
l′, cast-iron fly-wheel, at the summit of each rod L, in order to turn them by the hand.
M, large cast-iron cog-wheels, communicating with the moving wheel M′, and transmitting their movement to the two systems.
M′, vertical moving wheel in cast-iron, in two pieces, and adapted to the axle of a hydraulic wheel.
m, cast-iron bushing round each axle of the pinions; they can slide on it laterally.
m′, screw, by which the bushing is made to engage with its pinion; it is disengaged at will, when it is to put in or out of geer.
N, two cast-iron shafts, bearing the pinions M, and the bevel wheels O.
n, cast-iron fulcrum, having brass pillows, on which the turning pieces of the two shafts N rest; their plates are set in a groove made in the stones supporting them.
O, bevel with wooden cogs, and fitted to the shafts N.
P, cast-iron pinions.
Q, vertical shafts in cast-iron, turned their whole length, bearing the pinions P.
Q′, iron shaft, fitted to the summit of the preceding axles, and going towards the upper stories to work the cleaning bolting apparatus.
R, a horizontal wheel, with six arms, ending in ears pinned to the boxes of the millstones; its centre has three brass flat pillows, which keep the axle in a vertical position; force-screws press them at will.
o, keys, which maintain the pinions and the wheels S at the height determined for them, to prevent their fall, in case the screws which keep them fixed to their axle should become loose.
p, steel extremity of every vertical shaft to which it is adapted, having a conical shape; the contact suffices to keep them connected.
R′, great chair in cast-iron; the basis of which is solidly pinned to the stone R².
R², a large stone placed at the centre of the works, so disposed as to bear both systems.
q, rest-rod of the vertical axle; it is made of iron, flanged at its inferior portion, which goes through a nut in iron *r*.
r, nut, in iron, with square flanges, placed upon the centre of the base of R′.
r′, brass socket, adapted to a cast-iron muff, and containing a steel bed, similar to that of the millstone axles; it receives the point of the vertical shaft, and is governed by four screws.
S, a horizontal wheel, having fine wooden teeth, and fitted to the vertical shafts.
T, straight pinions, made of cast-iron, adapted to the axles of the stones, and to which the rotatory motion is given by the horizontal wheel S.
U, wooden box surrounding the millstones; it is placed upon the flooring of the first story.
V, brass hopper, distributing the grain to the stones.
s, zinc pipe, communicating with the hopper, which is placed in the second story. Valves open and close it.
t, brass tube, fitted into the lower part of the hoppers, and descending as far as *t*².
t′, small tube, enclosed within the last, when its opening is to be lessened before grinding the corn.
u, cross iron bar, the extremities of which are supported by screws; their office is to keep the tubes *t* at the desired height.
v, small cast-iron supports, attached to the lids of the millstone box.
X, a great circular shoot, in wood or sheet-iron, in which the ground corn is received at its exit from the stones; it rests upon the wheel R.
Y, spur-wheel, of cast-iron; it turns upon the vertical shaft, and gives attachment to the moveable branches of the shoot.
x, six iron branches, attached with pins to the ears of the wheel Y, which rotates them very slowly.
x′, wooden plates, fixed to the extremities of the branches *x*, they turn with them within the shoot, carrying forward the meal to the box of the endless screw.
y, pinion, commanding the wheel Y.
y′, strait wheel, cast with the preceding pinion, and fixed with it to an iron gudgeon, adapted to one of the arms of R.
*y*², a similar wheel on the vertical shaft, and transmitting its movement to *y*′.
Z, an endless screw, made of wood, having an iron axis and a wooden screw; it is inclosed within a rectangular box of wood, into which the meal from the shoot is received.
Z′, an oaken box, in which the ground grain falls.
z, a double pulley, mounted upon the extremity of the endless screw, and free on this axle.
z′, an endless chain, with tin buckets, fixed at intervals, in order to raise the meal from the box Z to the room where it is allowed to cool.
*z*², a small pulley, commanding the endless screw.

CORN ELEVATOR, *Steam: Pagin's Patent.* In the new warehouses attached to the Atlantic Docks, Brooklyn, there are several of these very useful engines erected. Also one on the river for discharging grain-laden ships in the stream or alongside the piers: the latter is called the floating elevator. The extremity of the shoot C is inserted in the hold of the vessel about to be discharged, its height being regulated by the guide-frame and pulleys, Fig. 1003. The machine is put in motion by means of the prime mover A and band-wheel B, when by means of a series of tin dippers attached to a belt of gutta percha or leather, tightly stretched over the wheels at B and C, the corn is brought up to a height

1003.



of 76 feet, and discharged by means of the small spout attached to the elevator into the weighing machine; from thence, by a repetition of the same contrivance, it is taken through the building to a shoot on the roof, containing an Archimedean screw, by the use of which and the elevator the grain may not only be placed on any particular floor in the warehouse, but may be transhipped (having been weighed in its passage) either wholly or partially for Europe, or any other destination.

This apparatus was erected by Barton, of Buffalo, and by means of a small high-pressure engine. 10-horse power, will raise 2600 bushels of grain 76 feet high per hour, and distribute or tranship as described.

CORN-MILL, *Old Union.* In order to render our series of Corn-Mill drawings complete, we have given in Fig. 1004 a representation of the arrangement of the stones, garners, &c., in an extensive establishment fitted by Mr. Fairbairn with machinery identical, in all important particulars, with that which we have detailed in the preceding figures and descriptions.

This mill contains seventeen pairs of stones. The whole are disposed in one straight line, close to the wall of the mill—which arrangement, on account of its undoubted superiority to any other, has

induced us to select this example. The flour produced is, for the most part, consumed by an extensive baking establishment adjoining the premises, and belonging to the same proprietors.

For our present purposes, we have deemed it necessary to give only a sectional elevation, on a small scale, and of a somewhat sketchy nature. The line of section must not be supposed to be taken in one vertical plane, but to vary in order to exhibit most distinctly the different parts.

Description.—Two powerful steam-engines are employed to drive the machinery of this mill; one of these communicates its motion to the line of horizontal shafting, near the end of the range, by means of a great bevel-wheel A, keyed to the crank-shaft, and working into the bevel mortise-pinion B upon the mill-shaft; the other, by means of a spur fly-wheel working into the mortise-pinion C, situated towards the centre of the range. By thus applying the power at two points, the weight of shafting and consequent loss from friction, &c., is materially diminished.

From the driving-shaft D D D, the power is communicated by the bevel pairs *a a a*, to the mill-spindles, which are provided with suitable bearings and adjusting geer, in all respects identical with that we have already described. Between the first and second pairs of stones, one of the standards E is employed for the purpose at once of giving great stability and firmness to the shaft D at the point where it receives the strain of the first engine, and of affording the means of transmitting its motion to the upright shaft driving the lighter machinery of the mill. A strong cast-iron bracket *b*, bolted through the wall of the mill, abuts against the framing, and the intermediate stays *c c* bind all three together laterally.

Each of the feeding hoppers *d d d* is supported by a light cast-iron framing *e*, resting upon slender columns; the tripodal form is, however, preferable to this.

The feeding-pipes H H H are of tinned plate, so constructed as to be easily withdrawn from their connection with the wheat-garners when the stones are taken up; and at the top of each is a small valve or slide *h*, to shut off the supply of wheat. Above these points the passage of the grain from the cleaned wheat-garners is effected by means of wooden spouts I I I, converging to and communicating with them.

The cleaned wheat-garners J J J are three in number, and are situated on the top floor of the mill, immediately over the stones. Between, and in front of these, are the garners K K, which receive the wheat as it is first brought to the mill, and deliver it, by means of numerous spouts or openings in the floor, to the great uncleaned wheat-garners L L, situated on the machine flat. From these the undressed wheat is conveyed, by means of a creeper and elevator, into the screen M, whence it falls through the spout P into an elevator on the stone floor, by which it is again raised to the upper story and distributed, by another creeper, into the cleaned wheat-garners J J J.

The vertical shaft *i i* is continued upwards till it terminates near the roof of the machine floor. Then its motion is transferred by means of a short transverse shaft, (which we have purposely omitted in our drawing for the sake of simplicity,) and two pairs of bevel wheels, to the long horizontal range of shafting *k k*, on which are fixed numerous pulleys for driving the various subordinate machinery of the mill.

The pulley *l* drives the lower creeper.
" " *m* " the upper creeper.
" " *n* " the sack-tackle.
" " *o* " the first elevator.
The pulley *p* drives the second elevator.
" " *q* " the fan (belt working over guide pulleys.)
" " *r* " the wheat-screen.

The dressing and bolting machines are driven by pulleys on the transverse shaft. The apparatus Q for raising the stones is shown here in action; it may be remarked that it is found necessary, in this mill, to keep a couple of stone-dressers in constant employment; each pair of stones being, in succession, thrown out of geer for twenty-four hours, to undergo the process of redressing.

Calculation of Velocities.

1st Steam-engine makes 48 Revolutions of Crank-shaft per Minute.
2d do. 22 do. do. do.

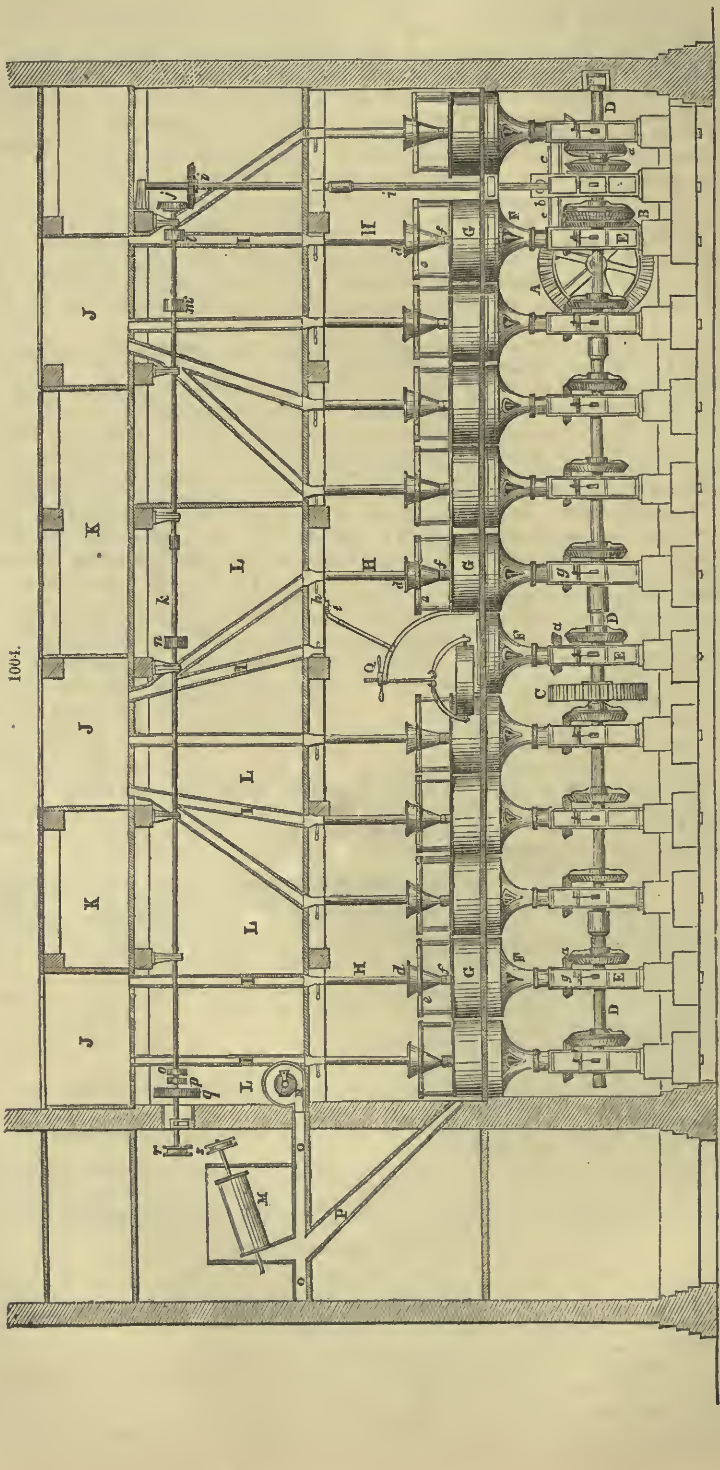
Description of geering.	Driver. Diameter. Ft.	In.	Driver. Revolutions.	Driven. Diameter. Ft.	In.	Result. Revolutions per Minute.
Bevel pair A B..........	6	8¾	48	4	6	71·57 on horizontal shaft D.
Spur fly-wheel into C...	18	2⅜	22	5	7	
Bevel pairs *a a a*.........	3	6	71·57	1	10½	132 on the millstones and upright *i*.
1st pair of small bevels	3	0	132	2	1½	184 on the transverse shaft.
2d do. do....	1	6	184	1	10	149 on the longitudinal shaft *k*.

Diameter of the millstones, 4 feet.

Literal References to Fig. 1004.

A, the great bevel-wheel on the crank-shaft of first engine.
B, the pinion on the mill-shaft working into the above.
C, a spur cog-pinion on the mill-shaft driven by the spur fly-wheel of the second engine.
D D D, the range of mill shafting.
E E E, the standards or lower framing of the mills.
F F F, the cones or upper framing of the mill.
G G G, the stone-cases.

1004.



Scale.—11 feet=1 inch.

a a a, the bevel wheels and pinions for driving the mill-spindles.
b, a strong bracket for strengthening the bearing of the pinion B.
c c, two cast-iron cross-stays for the same purpose.
d d d, the feeding hoppers.
e e e, the frames supporting the feeding hoppers.
f f f, the cast-iron moveable feeding-pipes.
g g g, the small screw and hand-wheel for working the feeding apparatus.
H H H, sheet-iron feeding-pipes from the machine floor to the hoppers.
h h h, slides for shutting off the supply of wheat when necessary.
I I I, wooden spouts or square pipes for leading the grain to the feeding-pipes H H H from
J J J, the cleaned wheat-garners on the top floor of the mill.
K K, the first uncleaned wheat-garners emptying their contents into
L L L, the great uncleaned wheat-garners on the machine floor.
M, the brusher or wheat-screen.
N, the fan attached to the wheat-screen.
O, passage of the blast, carrying the dust, &c., outside of the mill.
P, passage of the cleaned wheat to the second elevator.
i i, the upright shaft for driving the light machinery of the mill.
j, a pair of bevels between the upright shaft and
k, the range of longitudinal shafting down the mill.
l m n o p q r s, pulleys for driving the various light machinery.
Q, the stone-lifting machine shown in operation.
t t t, studs affixed to the beams supporting the machine floor, affording fixed centres for the working of the lifting machine Q.

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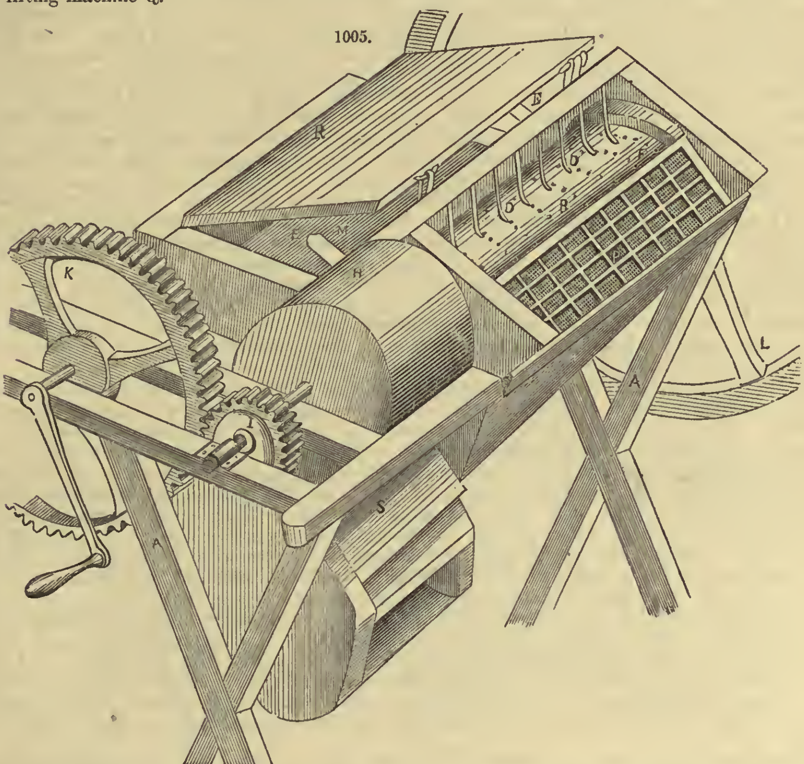


CORN-SHELLER. Fig. 1005 is a perspective view of L. M. Whitman's corn-sheller. A is the frame, B is a concave bed made of cast-iron plates, with projections on their inside surfaces. D is a cast-iron cylinder having projections cast on its outside surface. The ears of corn are fed in between the roller and the concave bed through M, on the other side of the lid R, and the cylinder being set in motion, are carried round between the cylinder and concave bed, and all the corn removed from the cob; the cob is carried round to the rake teeth seen above D D, and is thrown over the frame P, and falls over the side of the machine. The concave bed is hung on strong springs E E, which allow it to spring to the various sizes of the ears of corn—making it flexible for that purpose. The plates C, which form the concave bed, are placed a small distance apart from one another, so that the corn falls down between them into an inclined conduit, which carries the corn below H, a revolving set of fans, where the grain is perfectly cleaned; the dust, &c., being blown out through an opening below S. and the corn being heavier, passes into the granary or receptacle out of the opening T.

COROSOS, or *Nut Ivory*. See Woods, *varieties of*.

COTTON. The process of manufacturing into cloth.—The cotton from the bale is first sorted, and it is then subjected to the action of a large and powerful machine called a *willow*. This machine consists of an inner frame-work, capable of revolving with very great rapidity, and enclosed in an outer case. Upon the four edges of the inner frame are fixed a series of iron pins or pegs, which in their rotation pass between other similar pins fixed to the inner surface of the outer case. Now if a quantity of cotton be put in the receptacle between the inner and outer frames, and the inner one be made to rotate, the clotted locks of cotton, tossed about within the machine, are caught by the various iron pins, and torn open fibre by fibre. All the dirt and other impurities which may have been mixed with the cotton are at the same time separated from it, and made to fall through a kind of grating.

The next process is to complete the opening and cleansing thus begun. This process is called "picking." The cotton is laid upon a kind of endless apron, which by its movement conveys its burden to a fitting spot, where flat bars, carried rapidly around, strike the cotton violently as its exudes from between two rollers, and thus separates the fibres most thoroughly. There is also a particular kind of fan or vane, so arranged as to produce a powerful draught, by which all the dirt and dust are carried up and conveyed away—not only out of the machine, but out of the room, and out of the factory itself.

The cotton is now in the form of a very clean, light downy fleece called a lap, consisting of short fibres thoroughly disentangled. But these fibres are not *parallel;* they lie across each other at every imaginable angle, and any attempt to combine them together in this state would be fruitless: they must be rendered parallel, and to effect this is the object of *carding*. The cotton is brought into the form of a 'lap,' or flat layer by the "picker," and in that state transferred to the carding-engine.

The cotton leaves the carding-engine in the state of a delicate, flat, narrow strip or riband, called a *sliver;* and these slivers have now to be converted into *drawings* by being elongated, narrowed, and thinned to a still more delicate condition. In the first place the slivers are collected in tall cans, generally either four or six in number, on one side of '*drawing-frame*,' and are from thence carried upwards to two pair of rollers, the two rollers of each pair revolving in contact. Here all the slivers or cardings are collected into one group, and are drawn between the rollers by the rotation of the latter. Now if these rollers all revolved equally fast, the cotton would leave them with the same united thickness as when it entered; but the last pair revolve quicker than the first, so as to draw out the cotton into a more attenuated riband; because the more slowly-revolving rollers do not supply the material fast enough for the maintenance of the original thickness. This is perhaps the most important principle in the whole range of the cotton manufacture; for it is exhibited alike in the present process and in the next two which follow. All the four or six slivers are connected into one before being caught between the rollers; and after leaving the rollers, the united 'drawing' passes through a kind of trumpet-shaped funnel, and thence conducted into a tall can, round the interior of which it coils itself. One consequence of the drawing process, if properly conducted, is that the drawing is perfectly equal in thickness in every part, and formed of parallel fibres; and in order to ensure this, the drawing is repeated more than once, each narrow riband being 'doubled' with others before each successive drawing.

The slender ribands thus produced next pass through the 'roving-machine,' where they are brought to the state of *rovings*. In many respects the process of roving is similar to that of drawing, inasmuch as it draws out the cotton to a state of still greater attenuation; but as the cotton, in its now reduced thickness, has scarcely cohesive strength enough to make the fibres hold together, the roving has a slight twist given to it, by which it is converted into a loose kind of thread or spongy cord.

The 'bobbin-and-fly frame' consists of a system of vertical spindles, on each of which is placed a reel or bobbin, and also a kind of fork called a 'fly,' still farther removed than the bobbin from the axis of the spindle. The drawing or delicate sliver of cotton is first drawn through or between rollers, and elongated to the state of a roving; then this roving passes down a tube in one prong of the fork or fly, and becomes twisted by the revolution of the fly round the bobbin, while at the same time the twisted roving becomes wound with great regularity upon the bobbin. The machine in fact performs three different and distinct operations; it first attenuates the 'drawing' to a state of still greater thinness and delicacy than it had before; it then gives to the 'roving' thus produced a slight twist, sufficient to enable the fibres to cohere; and lastly, it winds this twisted roving upon a bobbin, on which it is conveniently transferred to the spinning-machine. Instead of the bobbin and fly frame, in this country the speeder and stretcher are more commonly used, especially on the coarse yarns.

We then come to the *spinning* process, which finally presents the cotton in a state fit for the weaver, by elongating the roving till it contain in thickness exactly as many fibres as are necessary to produce the required size of yarns, and twisting of these fibres into a compact thread.

In modern cotton-factories the spinning-machines partake of the character either of Arkwright's or of Crompton's machines, *i. e.* the *throstle* and *mule;* the first for the stronger, and the latter for the finer work. Some factories have both throstles and mules, arranged in different parts of the building.

The yarn produced by these two classes of machines is appropriated to various purposes according to its fineness, strength, hardness, smoothness, and other qualities. Some is employed as *warp* or long threads for coarse goods; some for *weft* or cross-threads; some for printing calicoes; some for fine muslins; some for cotton hosiery; some for bobbin-net; some for sewing-cotton.

But before the weaving is effected, there are many intermediate steps to be attended to, such as 'dressing,' 'beaming,' 'winding,' 'warping,' &c. The *dressing* is a process by which either melted size or flour paste is applied to the yarn used as warp, as a means of rendering it smooth and stiff. The threads of yarn spread out in a parallel layer, after dipping into a trough of paste, are rubbed by two moveable brushes, by which the paste is laid smoothly over the surface, and the threads are then dried by passing over steam-heated cylinders or boxes.

The long threads of a piece of cloth or cotton, called the *warp*, are fixed to the weaving-loom, while cross-threads called the *weft*, are fixed to the shuttle. The process of 'winding' is that by which the

weft is transferred from the bobbins to the shuttle, and is done in a very simple manner by means of a wheel. The process of 'warping' is more complicated. Supposing there to be a thousand threads in the width of a piece of cloth, then the yarn, wound on the bobbins as it leaves the hands of the spinners, must be so uncovered and laid out as to form a thousand lengths, constituting, when laid parallel, the warp of the intended cloth.

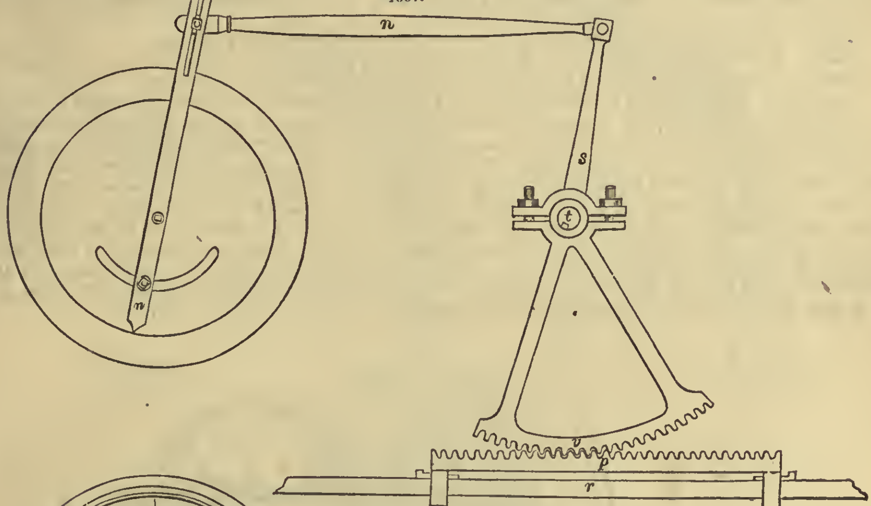
The arrangements here described are for the purpose of arranging parallel as many threads as will form the width of the piece of cloth to be woven; and all these threads collected are called the *warp*. This warp, being removed from the warping-mill or frame, is next 'beamed,' or wound on the beam of the loom. The threads in this latter process are wound as evenly as possible on the beam; a kind of comb being used to lay them parallel, and to spread them out to about the intended width of the cloth. Arrangements are then made for drawing or attaching the warp-threads individually to certain mechanism of the loom. At about the middle of every heddle or string is a loop or eye, through which the warp-yarns are drawn, one through each eye; and the passing of the yarns through these loops constitutes the 'drawing.' Half of the warp-yarns, that is, every alternate yarn, pass through the loops in one leaf of *heddles*, and the other half through the other leaf; and as the two leaves are so connected by pullies as to cause one to rise when the other sinks, the warp becomes divided in two portions, one above the other, near the anterior end of the loom.

COUNTER. See GAS.

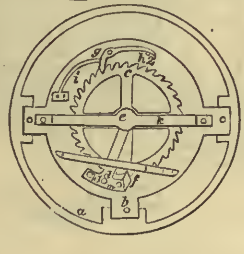
COUNTER PROPORTIONAL, by W. H. Lindsay. The construction and operation of this instrument, will, with the aid of the drawing, be readily understood.

Whatever distance or quantity a space from point to point, as from 3 to 4 on the outer circle of the dial-plate, is intended to represent, is attained by proportioning the arm *n* 2, and the segment of toothed-

1007.



1008.



wheel *v*, to the length of the stroke made by the rack *r*. To facilitate the adjustment with the greatest accuracy, the radius of the counter-arm *n* 2 can be lengthened or shortened by means of the pin *w*, which can be shifted up or down in the slot; and when the proper distance is obtained, made fast by a nut on the back side of the arm. The ratchet-wheel *c*, and centre pin *e*, which passes through an eye in the shoulder of the cross-piece *k*, on the frame *b*, give motion to the dial hands. The ratchet-wheel is moved in proportion to the length of stroke communicated to the counter-arm *n* 2, by means of four or five pawls or catches *f*, each a little longer than the other: for instance, if the space between two teeth on the ratchet-wheel be divided into four equal parts, and four or five pawls are used, they are each longer than the other by that distance; by which means, one or more of the set are always in contact

with the tooth nearest their points, thereby obtaining a continuous bearing or hold of the ratchet-wheel, without the possibility of the least slip or play. The moveable pawls *f* all work on the same centre or pin on the arm *d*, which works on the same centre as the ratchet-wheel. The pawls are made of steel; their points are kept in contact with the tooth nearest to them, by means of the curved elongation of each pressing against the pin *h* 1 on the off-side of the arm, to prevent the least slip or return of the ratchet-wheel during the back travel of the arm with the pawls, or whilst the pawls are moving back over the teeth. Catches *g*, of the same construction and number as those on the arm, are placed on the frame *b*, working on a pin in it, so that their ends are pressed into the space between the two nearest teeth on the ratchet-wheel, to render the stop-catches more effective. The ends of the spring *i*, which is a piece of brass bent or curved, and slit into as many pieces as there are catches for it to act on, presses against the curved part of the catches. The guard *l* crosses the arm *d*, keeping the arm and catches steady when moving. The pin *m*, in the centre of the arm, passes through the slot in the back of the counter, to which the counter-arm is made fast by a nut.

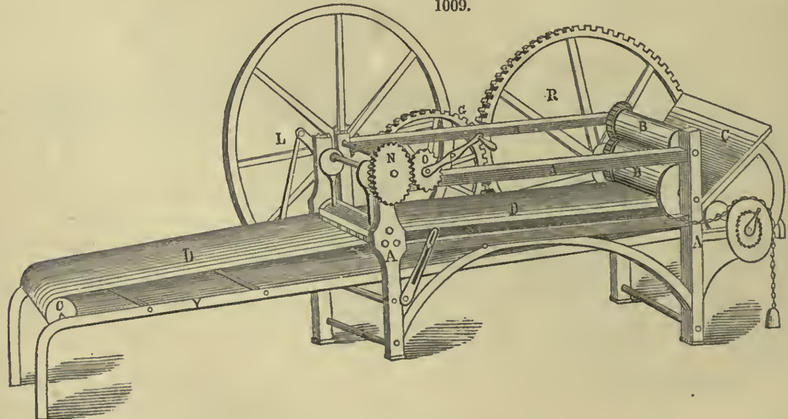
The counter's operation requires but little explanation: the length of stroke of the rack being determined, say 12 inches, and the pin in the slot adjusted by that length of travel, so that the hand on the outer circle of the dial-plate exactly makes a space, as from 3 to 4. Whatever distance within 12 inches the rack moves forward, say 3, 5, 8, or 10 inches, it will give motion to the ratchet-wheel and hand only in that proportion, the stop-catches allowing the ratchet-wheel to move round during the forward motion of the rack; but on the back travel of the rack-arm and catches, they being pressed by their own as well as the springs *i* into the space between the teeth nearest their ends, prevents not only the return of the ratchet-wheel, but also the least slip or return, by which means the face hands remain where they were carried to during the forward motion of the rack; from which it will be seen that whatever the index, or from point to point on the outer circle represents whether distance or quantity, by communicating motion to the rock a given distance, it will, on inspection of the dial-plate at any time, be found what has been performed.

COVE. Any kind of concave moulding; the concavity of an arch or of a ceiling.

CRAB. A moveable machine, made similar to a capstan, and used for similar purposes. The term is sometimes employed for a species of moveable windlass, fitted with geers and cranks.

CRACKER AND BISCUIT MACHINE. It is highly important where large quantities of biscuit are made for sea, either for the commercial or war marine, that there should be some machine for the speedy preparing of such kind of provisions, so as to preserve the flavor and quality of the flour, which we well know is not the case with all kinds of bread, as some will not keep fresh longer than two or three days. The machine represented in the engraving was patented some years ago by W. R. Nevins; and although there have been a number of machines built for the same purpose, yet good judges have pronounced it to be the best machine of the kind in existence, and in its present improved condition, without a rival. One of these machines was put up at St. Augustine during the Florida war, and it was of great benefit to the troops there. It has been examined by commissioners of the British navy, and has met their entire approbation. The Brazilian government has also requested one to be sent them, and there are others in use at Norfolk, Va., and Louisville, Ky.

1009.

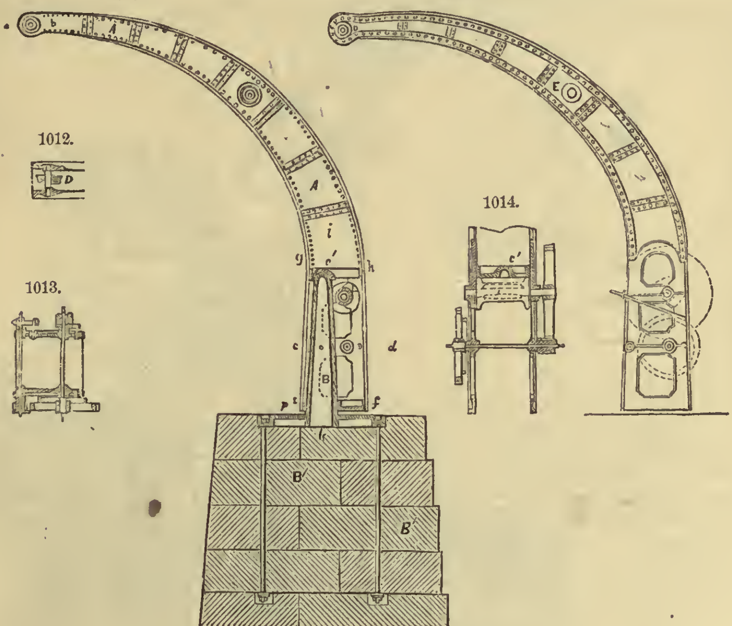


Description.—A A A A is the frame. B B are two feeding-rollers, the dough being fed into them on the board C. D D is an endless band the same width as the feed-rollers. This band is for carrying the dough from the feed-rollers to the cutters and forward off the cutters on the band-frame Y, to be taken off after the dough is cut into the desired size and form. The frame Y, on which the band D runs over the roller C, can slide under the machine when the machine is not in operation, so as to occupy as little room as possible. P is a crank for working the machine, and on the crank-shaft is a cog-wheel O, meshing into a larger cog-wheel N. The cog-wheel N moves the cutters, not in a rotary motion, but up and down, cutting the biscuit clean by the reciprocating motion ingeniously combined with the rotary by two eccentrics on the shaft, which will be observed between N and the larger, or fly-wheel, on the

other side of the frame. While the cutters are moved by N, the shaft of O gives motion to the cog-wheels on the other side of the frame, and by the accumulation of power on the fly-wheel the whole apparatus is very easily worked. The cog-wheel G meshes into the cog-wheel R, for the purpose of giving the feed-rollers a uniform speed, something very necessary, as bakers know, so that there may not be too much friction by the rollers, in which case crackers and biscuits are afterwards apt to split open, and in warm latitudes soon spoil. The endless band is made to bring forward the dough by two cranks, one seen on the opposite side of the frame, inside of the fly-wheel, which works a pendulum shaft below the handle P, on which is a cord passing over a pulley at the end of the feed-board C; on the end of this cord is a weight which works by the pendulum the toothed pulley, on which is a clamp to slip and cut the exact distance the band is wanted to move for every cut of the cutters, for the band D passes over the roller of the toothed pulley, on which is the cord, and round by C. There is a slot in the pendulum shaft, so that the pin can be moved up or down, for a long or short cut, and by the shifting or changing the tooth-wheels O and N, the speed of the cutters will be increased while the rest of the machine keeps a uniform motion. It will be observed that the cutters do not fall or press down upon the canvas direct from the shaft, there is a plate between the canvas and the cutters, so that a fine clean cut is made through the dough.

One of these machines with cutters only for three biscuit in the breadth of the frame, has cut as fast as one in use in the British navy with fifty cutters, thus showing a great superiority. But the best recommendation comes from those who have them in operation, Mr. Stratton, of Brooklyn, and Mr. Wilson, of this city, who speak in the highest terms of their qualities. This machine is the invention of Mr W R. Nevins, No. 609 Greenwich-street. New York, who manufactures them.

1010. 1011. 1012. 1013. 1014.



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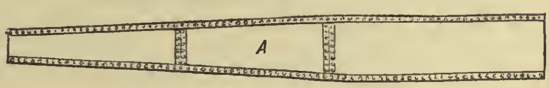

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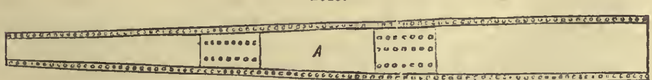
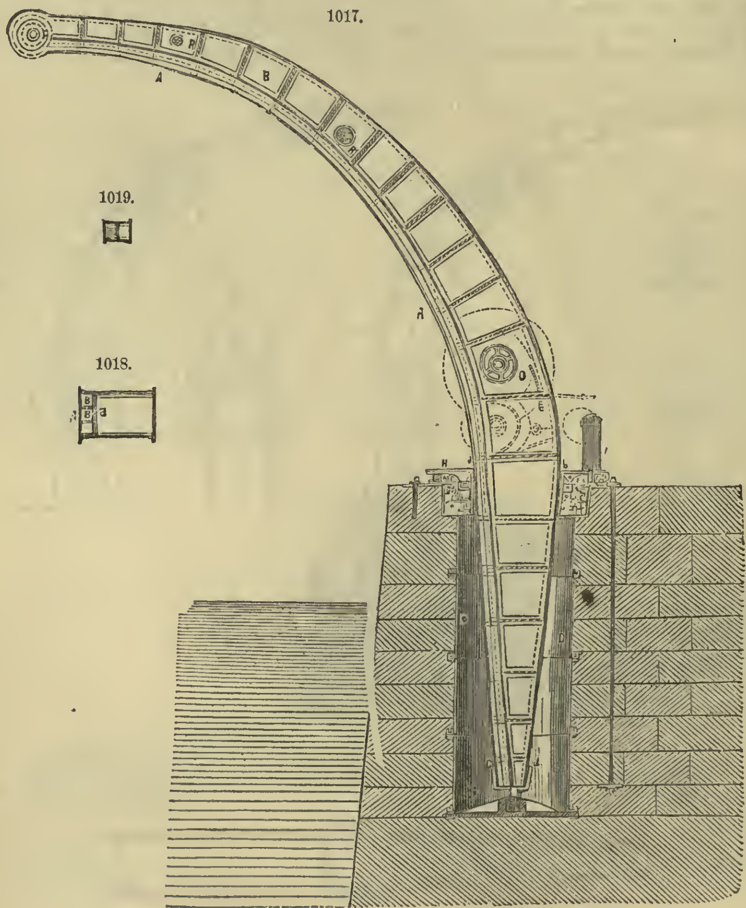


CRANES. Fairbairn's Tubular Cranes. These improvements consist in constructing the jib of such machines of metal plates, so arranged and combined as to form a connected series of tubular or cellular compartments, instead of forming the jib of one solid piece as heretofore.

Fig. 1010 is a vertical section of a crane constructed according to said invention, and calculated for lift-

ing or hoisting weights up to about eight tons. Fig. 1011 is an elevation of the same; figs. 1012 and 1013 are cross sections on the lines *a b*, *c d;* and fig. 1014 a transverse vertical section on the line *i k*. A A is the jib, which in its general outline is of a crane-neck form, but rectangular in its cross sections, as shown in fig. 1013. The four sides are formed of metal plates firmly riveted together. Along the edges, the connection of the plates is effected by means of pieces of angle iron. The connections of the plates at the cross joints, on the convex or upper side of the jib, are made by the riveting on of a plate which covers or overlaps the ends of the two plates to be joined; the rivets at this part are disposed as represented in fig. 1015 (a plan of the top plates), and known as "chain riveting." B B is the pillar which is firmly secured by a base plate *p*, to a stone foundation B,[1] and fits at top into a cup-shaped bearing C[1], which is firmly secured to the side plates of the jib, at or near to the point where the curvature commences, and on which bearing the jib is free to revolve. Fig. 1014 is a transverse vertical section of the lower part of the jib, showing the manner of fitting the bearings for the chain barrel, (which is placed in the interior,) and the spindles and shafts of the wheel gearing by which the power is applied thereto. D is the chain pulley, which is inserted in an aperture formed in the top of the jib. The chain passing over this pulley enters the interior of the crane, and is continued down to the chain barrel. E is a pulley or roller, which is interposed about half way between the chain pulley and the chain barrel, for the purpose of preventing the chain rubbing against the plates. Fig. 1016 is a plan of the lower plates.

1017.



1019.

1018.

Fig. 1017 is a vertical section of another crane, constructed on the same principle as that which has just been described, but calculated for lifting much greater weights (say 20 tons); it differs in having the lower or concave side A A of the jib strengthened by means of three additional plates B, B, B, whereby the interior is divided into one large and three smaller cells, as shown in figs. 1018 and 1019, which are cross sections on the lines *a b* and *c d* of fig. 1017. This arrangement of the cells to strengthen the lower or concave side is advisable, in order to obtain sufficient resistance to the compression exerted by the load lifted, without unnecessarily increasing the weight of the other parts.

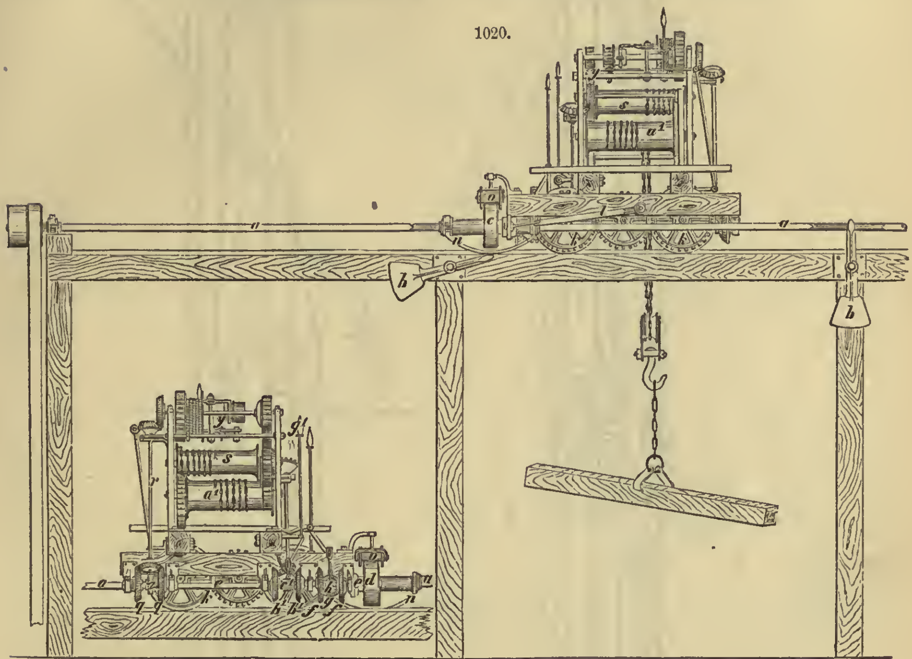
Travelling cranes are constructed somewhat similar in their upper works to the Foundry Crane, figs. 1025, 1026; but instead of a single post or support, there are two horses or spreading frames which are

supported on trunks, admitting of traverse in one direction on a line of rails, whilst the truck, as E F fig. 1026, admits of a motion at right angles to the former.

McNicoll and Venon's PATENT STEAM TRAVELLING CRANE.

This machine, like the ordinary hand travelling crane, moves upon a tram road laid upon longitudinal beams, raised from 15 to 20 feet above the level of the ground, the beams being supported at intervals by uprights. A square shaft *a*, (figs. 1020 and 1022,) $2\frac{1}{2}$ inch diameter, runs the entire length of the tram road, and is attached to the longitudinal beams by movable support, *b b b*. This shaft is connected at one extremity to the engine. Upon it, and revolving with it, is placed a drum, *c*, which works by means of a leather belt, the pulley *d*, attached to the moving platform. The pulley *d*, is fixed on th shaft *e*, upon which are placed the bevel wheels, which impart the threefold motion to the crane. Th

1020.

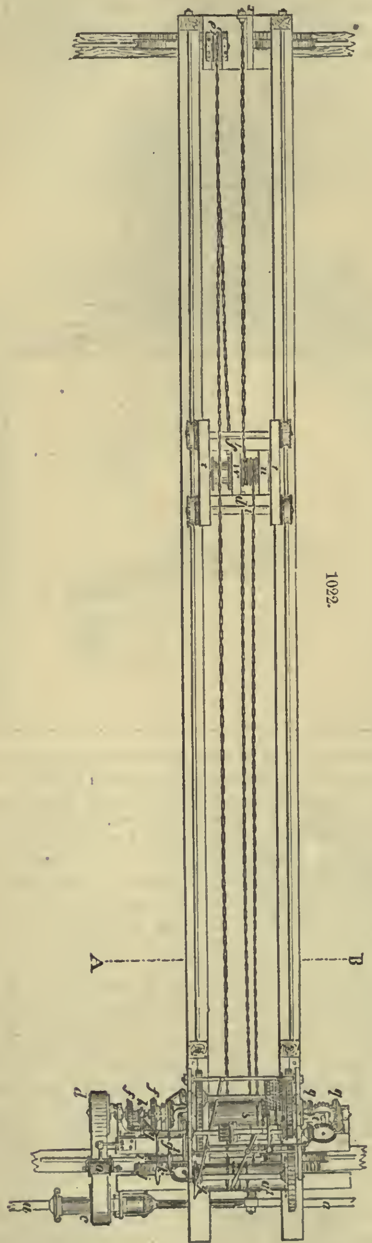


bevel wheels *f f*, which revolve freely on the shaft, are made so as to turn the bevel wheel *g*, by means of the clutch box *h*, which is attached to the shaft; so that by withdrawing the clutch box from one of the bevel wheels and putting it in gear with the other, the motion of the bevel wheel *g*, is reversed, and when the clutch box is out of gear the bevel wheel *g* is stationary. The bevel wheel *g*, is fastened upon the small shaft *i*, to the other end of which is attached the pinion *j*, which works the spur wheel fixed to the roller wheel *k*, and imparts the longitudinal motion to the whole platform. As the platform would otherwise move away from the drum *c*, which communicates the motion, it is made to slide freely upon the shaft, and being attached to the moving platform by means of the rod *l*, it always preserves its relative position with regard to the pulley *d*. The difficulty of making the drum pass over the numerous brackets, that a long shaft must necessarily have to support it, is overcome by making the brackets swing on a centre, so that when the drum *c*, protected by the guard *n*, comes in contact with one of the brackets, *b b*, it yields as shown in fig. 1020, and allows the drum to pass over it. Immediately it has so passed, the weight of the lower extremity of the bracket causes it to resume its position, and the machine passes on to the next bracket, where the operation is repeated. In order to prevent the shock that would be felt in putting in motion so heavy a body as a travelling crane of 50 feet span, carrying in addition to its own weight, a load of 3 or 4 tons, a friction roller *o*, is made to press upon the leather belt that passes round the drum *c*, and the pulley *d*, so that before putting the machine in gear, the friction roller is raised; the machine is then put in gear, and the friction roller gradually lowered. The momentary slipping of the belt round the pulley *d*, when the weight of the friction roller is only partially resting upon it, causes the machine to move forward with an easy motion, and directly it is under way, the friction roller is allowed to bear with the whole of its weight, and the crane then moves forward with its load, at its usual speed of 100 feet in 45 seconds.

The hoisting motion is obtained by communicating the power through the bevel wheels *q q*, and the shaft *r*, to the barrel *s*, round which the chain revolves. In order to render the hoisting motion independent of the transverse motion, the hoisting chain passes from the barrel round which it is coiled to the truck *t*, and after passing over the pulley *u*, under the snatch block *v*, and over the pulley *w*, it is finally attached to the point *x*, at the extreme end of the platform. To hoist a weight therefore, it is merely necessary that the handle *y*, which communicates with the clutch box *z*, should be moved a few inches.

The transverse motion is imparted to the load by means of the barrel '*a*, which is worked from th

shaft e, by the bevel wheels $'b\ 'b$, and clutch box $'c$, in the same manner as the longitudinal and the hoisting motions. Two chains are attached to the barrel in such a way, that one winds when the other unwinds. One of these chains is attached to the small truck t, at $'d$, and the other is carried round the pulley $'e$, and fastened to the truck at $'f$, so that by alternately pulling the clutch box $'c$, in geer with one or other of the bevel wheels $'b\ 'b$, by means of the handle $'g$, the truck, and with it the load, is moved backwards or upwards along the platform at right angles with the motion of the platform itself.



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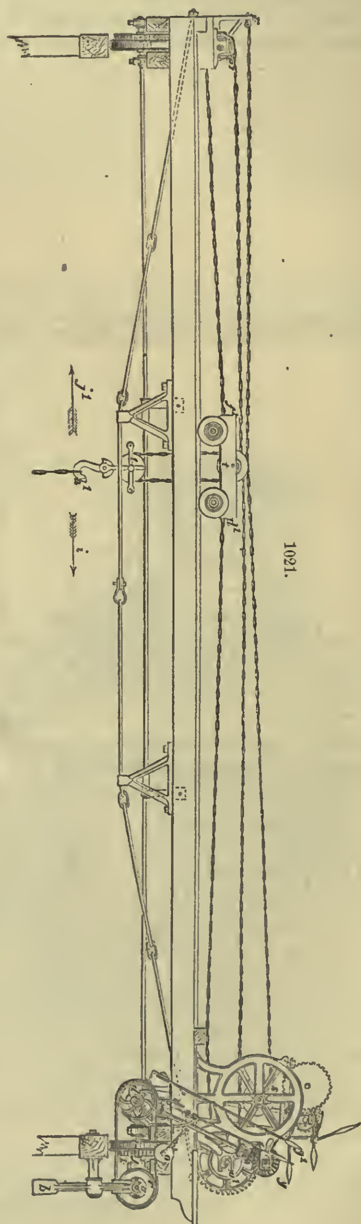
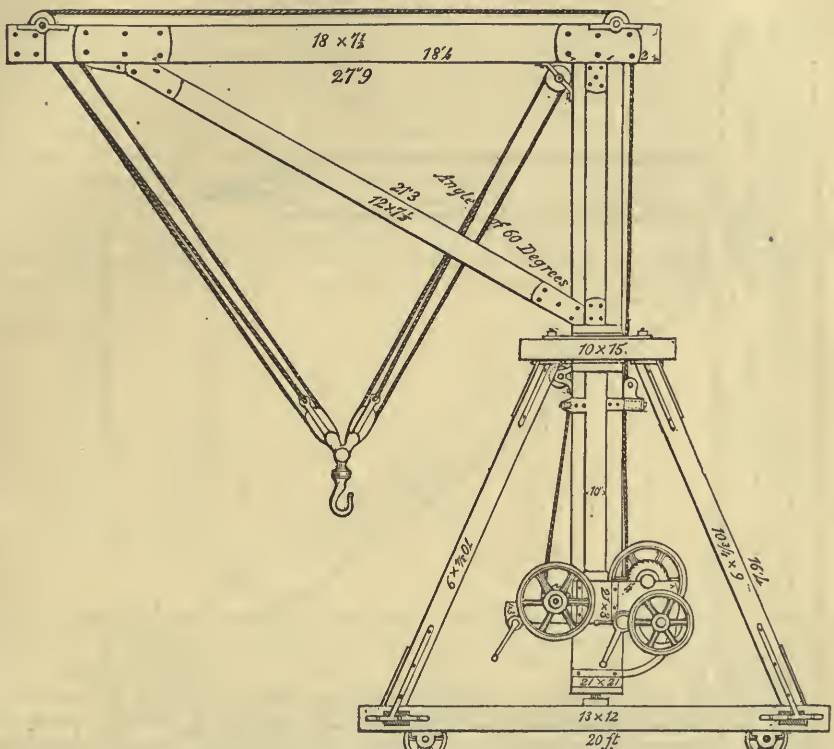


1021.

Each of the above—the longitudinal, the transverse, and the hoisting motions, can be used independently of either of the others; or any two of the motions may be used in combination; or the whole three may be used simultaneously. For instance; at the same time that a weight attached to the hook $'h$, is being raised from the ground by the barrel s, the truck t, and consequently the load suspended on the chain, may be moved in the direction $'i$ or $'j$, at the same time that the longitudinal motion is imparted to the whole platform by the roller k.

Fig. 1023 represents an elevation and fig. 1024 a plan of a moveable crane, arranged and used for laying the voussoirs in the inverted arches of the United States Dry Dock at Brooklyn, New York, by Wm J. Mc Alpine, predecessor to Mr. Stewart, the present Chief Engineer.

1023.



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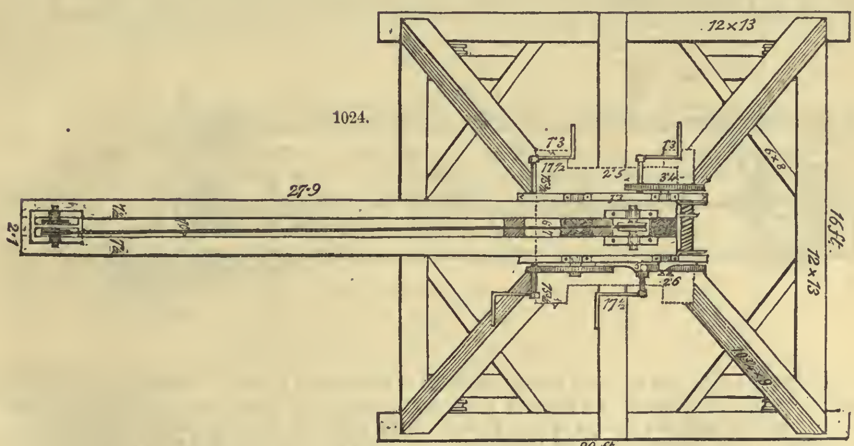


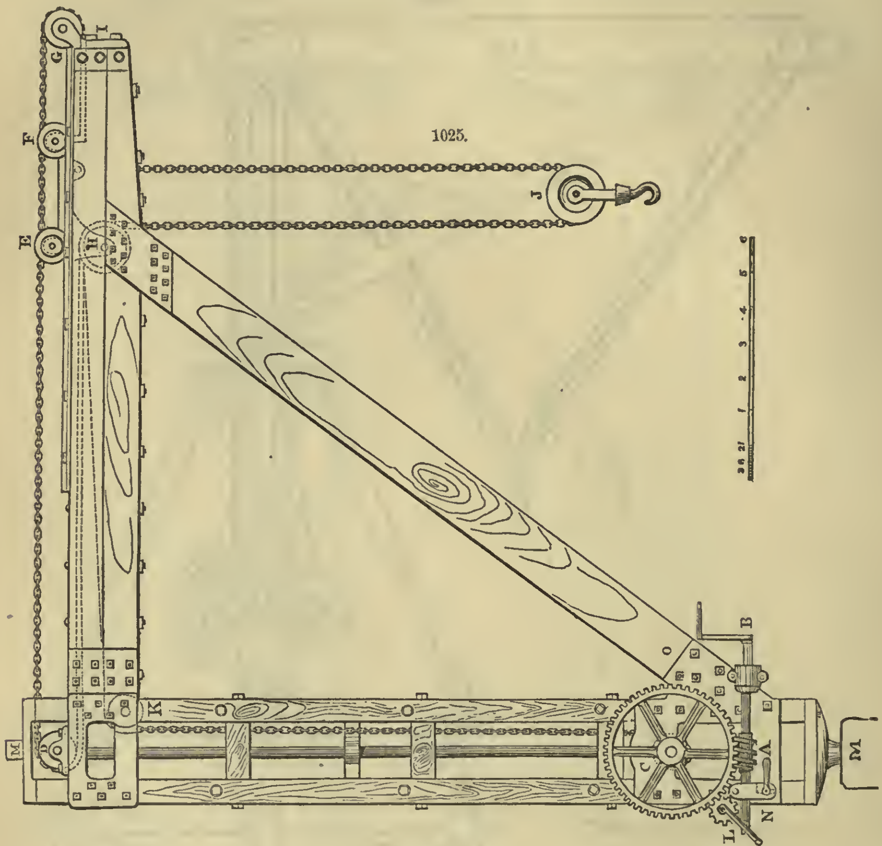
Scale.—8 feet=1 inch.

This crane has been used for hoisting stone weighing from ten to fifteen thousand pounds, at the extremity of the arm, which describes a circle of fifty feet diameter. It has also been used with an outrigger, by which stones from three to five tons weight were hoisted ten feet beyond the extremity of the arm.

A similar crane was used by the same engineer in the construction of the locks of the enlarged Erie Canal. A moveable sheave traversed along the arm of the crane, which was laid on an inclination

towards the mast of twenty degrees. By the use of the "Siamese blocks," the stone is moved towards or from the mast and hoisted or lowered with the accuracy requsite for setting fine-cut stone

1025.



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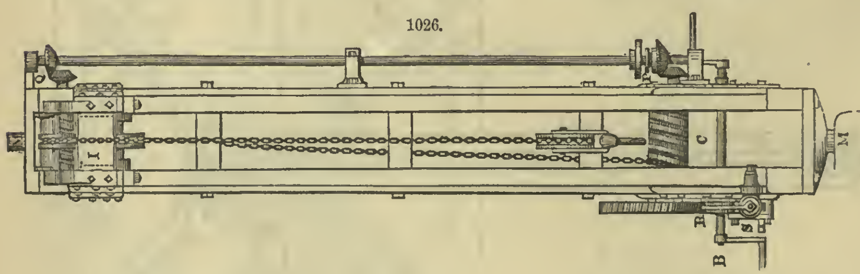


Fig. 1026 is a side, and fig. 1027 an end elevation of a FOUNDRY CRANE as constructed at the Lowell Machine Shop. It is operated as follows: the weight is suspended from the sheave J, and is raised by the chain passing over the pulleys H and K, and around upon the barrel C, either by the boom A or the pinion L, according to the weight to be raised. The pulley H is suspended from a carriage supported by the wheels E and F, traversing on rails at the top of the cope. Motion in or out is given to this carriage by means of the upright shaft and bevel wheels at B and P, which causes the drum D to revolve, and draw either at the upper part of the chain, which passing over the pulley G, is attached to the outer extremity of the carriage, or at the lower part of the chain, which is fastened to the inner extremity.

CRANE. See DERRICK.

CRANK. Elucidation of the principles of the action of the crank as used for the conversion of a reciprocating into a rotary motion. With a pair of compasses describe a circle, draw a line through the

centre; from one point of the intersection of this line with the circle divide the latter into twenty equal parts, 20 and 10 occurring at these points: now suppose that the constant pressure of the steam in the cylinder be represented by 100, this pressure is communicated to the crank by means of a connecting-rod, and we will suppose that the above circle is the circle described by the crank-pin 0 and 20 coinciding, and with the division 10 forming a right line with the centre of crank-shaft and the centre of the cylinder; of course the point 0 or 20 and the point 10 are the two points where the pressure in the cylinder has no effect in turning the crank, called the "dead points." The points 5 and 15 are the points at which the effects of the pressure on the piston is a maximum, decreasing each way to zero. Supposing, for simplicity, the direction of the connecting-rod to remain parallel with its first position, then the effect of any pressure communicated by it to the crank-pin is resolvable into two; one acting on the centre of the crank, and of course inoperative towards producing motion in it, and the other acting tangentially to turn the crank. The first of these is greatest at the commencement or 0 and 10 of the circle of the crank, and least at the points 5 and 15, while the second is least at the first-named points and greatest at the last; and this variation is (from the well-known principles of the composition and resolution of forces) in the ratio of the sines of the angle made between the direction of the crank and the direction of the connecting-rod.

The subdivision of the crank circle into 20 parts gives as the angle of each division 18°, and calling the radius of this circle 100, the sines of the respective angles formed by the crank and connecting-rods will represent the per centage of power communicated by the latter to turn the former. Thus:

Crank-pin at	0	0°		0·0
" "	1	18°	Sin.	30·90
" "	2	36°	"	58·78
" "	3	54°	"	80·90
" "	4	72°	"	95·11
" "	5	90°	"	100·
" "	6	108°	"	95·11
" "	7	126°	"	80·90
" "	8	144°	"	58·78
" "	9	162°	"	30·90
" "	10	180°	"	0·0
			Mean power	63·11

The pressure of the steam on the piston forces the connecting-rod twice the length of the diameter of the circle, in the same time that the crank-pin travels through a space equal to the whole circumference of this circle, and as the circumference of this circle bears to twice its diameter the ratio of 100 to 63·6, it follows that the pressure on the crank and piston are inversely as the spaces through which they move. The effects of moving powers may be represented for comparison by the product of the pressures, into the spaces described in the same time. The power of the steam in the cylinder being 100, and moving through a space represented by 2, we may represent it by 200, and the mean pressure on the crank, as shown above, being 63·11, moving through a space represented by 3·1416 we may represent its effect by their product 198·26, differing but 1·74 from the power given out by the steam in the cylinder. This difference will appear smaller and smaller according as we multiply the number of points in the circle from which we calculate the mean pressure on the crank, until finally the differences become so small as to satisfy us that the discrepancy arises solely from our inaccurate approximation, and the things are, in truth, equal.

The above calculation, when made by means of the differential calculus, shows that the crank is no consumer of power (beyond the friction incidental to all motion of machinery), but gives out all the power it receives from the steam.

In the year 1849, the Society of Arts offered a prize "for the best collection of diagrams (with explanations) to illustrate the action of the forces on a crank or cranks turned from a horizontal direct-action steam cylinder or cylinders; the effect of various proportions of connecting-rods, and degrees of expansion of steam, being shown."

The present paper was communicated to the society in accordance with their invitation, by W. Pole, C. E., and obtained the silver Isis medal.

The varieties of expansion, taken in these diagrams, are three, viz.:

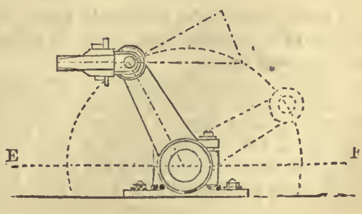
Steam admitted during the whole stroke (Nos. 4, 5, 6).

" " half the stroke (Nos. 7, 8, 9).

" " one-fourth the stroke (Nos. 10, 11, 12).

The varieties of length of connecting-rod have also been taken at three, viz.:

No. 1.



Connecting-rod indefinitely long (supposed to act always in parallel directions.) (Nos. 1, 4, 7, 10).

Connecting-rod five times the length of crank, which may represent about the ordinary length. (Nos. 5, 8, 11).

Connecting-rod three times the length of crank, or about the shortest made. (Nos. 6, 9, 12).

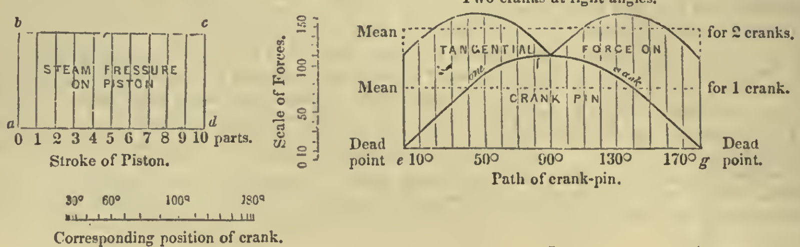
Diagram No. 1, is explanatory of the action of the forces in the transmission of the power from the piston to the crank, for an indefinite length of connecting-rod. The piston rod is shown by the long dotted line

The object of diagrams Nos. 4 to 12, is to exhibit the values and variations of the forces at the beginning and end of the engine; *i. e.*, the pressure of steam on the piston, and the force turning the crank round.

Each set of these diagrams contains a figure showing the pressure on the piston at all points of the stroke, on the plan of rectangular co-ordinates; the abscissa representing the space passed over by the piston, and the ordinate the corresponding pressure. Thus, when the piston has moved from 0 to x, No

4.

Two cranks at right angles.



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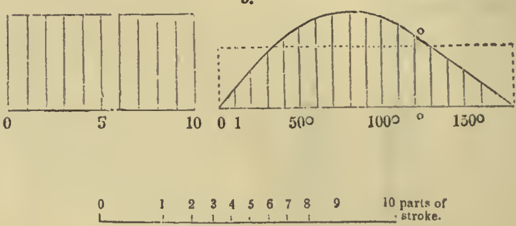
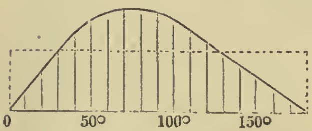


Corresponding position of piston.

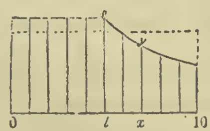
6.



7, or $\frac{7}{01}$ of the whole stroke, the steam pressure upon it is represented by the line $x\,y$. The scale given under the left-hand figure, in Nos. 4, 5, 6, and which also applies to Nos. 7 to 12, shows the position of the crank corresponding to any given position of the piston: thus, in No. 6, it is seen, by inspection, that when the piston has passed through $\frac{5}{10}$ of its course, the crank has passed through about 81° from the dead point, and so on.

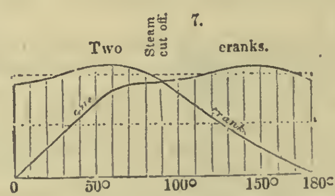
The right-hand figure in each diagram represents the tangential or working force, acting on the crank-pin, at every point of its semi-revolution from E to F, Nos. 1, 2, and 3. The curve of this figure is also laid down by rectangular co-ordinates: the path of the crank-pin (reduced to a straight line) forms the line of the abscissa, while the ordinates express the corresponding forces. Thus in fig. 5, when the crank-pin has moved from 0 to o, or 120° from the dead point, the tangential force, tending to turn it round, is represented by the line o o.

7.

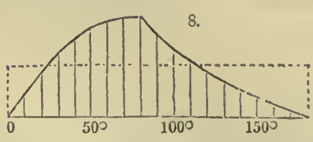


7.

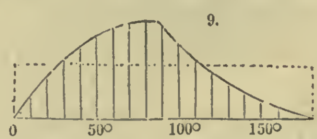
Two cranks.



8.



9.



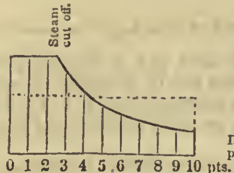
The additional scale, under this figure, shows the position of the piston corresponding to any given position of the crank: thus, in fig. 5, when the crank is at 140°, the piston has moved through $\frac{9}{10}$ of its stroke, and so on.

The lines representing the forces are measured by a scale, which is appended to fig. 4. The pressure of the steam upon the piston, while the steam-valve is open, is made = 100 on the scale; and the ratio of any other force to this pressure is therefore easily ascertained by simple measurement.

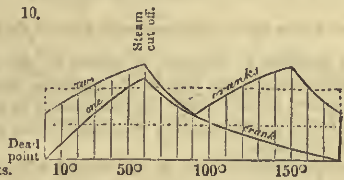
In No. 4, the connecting-rod is supposed indefinitely long; the pressure on the piston is uniform at 100. The tangential force on the crank-pin begins at 0 when the crank is at the dead point; increases to 100 when it arrives at 90°; and diminishes again to 0, in the same ratio as the increase. The mean value of the force, throughout the semi-revolution, is = 63·6, which × the space passed through by

the crank-pin, is exactly = the pressure on the piston + the length of its stroke; or, in other words, the area of the figure $e f g$ = the parallelogram $a\ b\ c\ d$. The result is in accordance with the principle of "conservation of *vis viva*," by which we know that (neglecting friction) the amount of power or work given out at the crank-pin is equal to that performed by the steam on the piston.

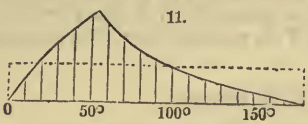
In No. 5 is seen the effect of the connecting-rod being made five times the length of the crank. Here the tangential force commencing at 0, arrives at a maximum value of about 102 when the crank has passed through about 80°



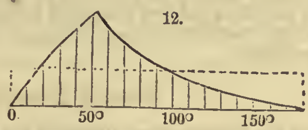
10.



11.



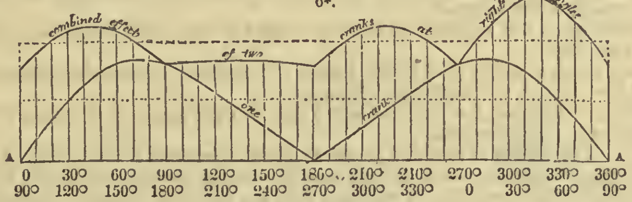
12.



In No. 6, where the connecting-rod is three times the length of the crank, the tangential force arrives at a maximum value of about 106 when the crank has passed through about 75°.

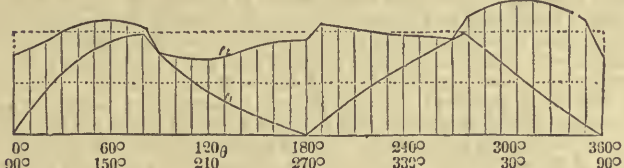
It will be perceived, however, that these variations make no difference in the mean force throughout the whole figure; the effect of the connecting-rod being merely to vary, in a slight degree, the distribution of the force over the path of the crank-pin, without affecting the total amount of power conveyed to it by the machinery. The comparative merits of long and short connecting-rods in other points of view, involve considerations which it would be out of place to introduce here.

6*.

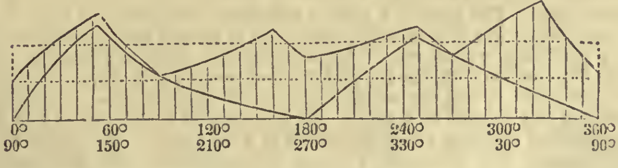


A A′, path of the two cranks.

9*.



12*.



The return stroke, or the other semi-revolution of the crank, does not exactly correspond with the figures shown in diagrams 5 and 6, owing to the reversed condition of the connecting-rod. The nature of the variation will be seen in fig. 6*, where the tangential force is shown for an entire revolution of the crank. It will be observed here, that the force at 10° (commencing at A′) corresponds with that at 350°, at 60° with 300°, and so on.

Nos. 7, 8, 9, show the effect of cutting off the steam at half the stroke. Here the mean pressure on the piston is = 84·6, and the mean tangential force on the crank-pin is = 54; the equality between

the areas of the right and left hand figures being still preserved. The power of the engine is diminished in the proportion of 1000 : 846, although the economy is much increased, as is well known.

Nos. 10, 11, 12, show the effect of cutting off the steam at one-fourth of the stroke. Here the mean pressure on the piston is = 59·6, the mean tangential force is = 38; and the power of the engine is reduced from 100 to 59·6.

Nos. 9* and 12* show the values of the tangential force through an entire revolution of the crank, in the cases above alluded to under corresponding numbers.

Combined action of two Engines, with Cranks fixed at right angles with each other.

The effect of two engines, so coupled, is shown in six cases out of the nine previously described, namely, with three variations in the degree of expansion, and two in the length of connecting-rod. The curve of tangential forces is laid down for two cranks in diagrams Nos. 4, 7, 10, 6*, 9*, and 12*; in the three former, for half a revolution (the other half being precisely similar), and in the three latter, for a whole revolution of the crank.

It is presumed that these figures will be understood without any further description. As an example: at θ (No. 9*), one crank is supposed to have travelled 130° from the dead point E (No. 3); the tangential force on it being expressed by the line $\theta\,\rho^1$: the second crank will then have travelled 220° from the same point; and the combined tangential force will be represented by the line $\theta\,\rho^2$. The undulations of the upper line will therefore represent the inequalities of the working power in the crank-shaft throughout its whole revolution.

Method of Construction of the Diagrams.

In laying down the forces in these diagrams, the following points have been assumed

(*a*). That as long as the steam-valve remains open, the pressure of the steam in the cylinder is uniform. This is not always the case in practice, but must generally be assumed in calculation.

(*b*). That after the steam-valve is closed, the steam expands according to Marriotte's law; the pressure varying inversely as the volume. This is the usual assumption. The causes of variation from this law are treated of in works on the steam-engine, but cannot be comprehended in an investigation of the present nature.

(*c*). That no power is lost by friction, in the transmission of the force through the machine.

(*d*). The influence of the clearance space on the volume of the steam, in expanding, has been neglected. This is but of small moment; and its introduction would have interfered materially with the simplicity and clearness of the diagrams.

(*e*). The moving parts are supposed to have no weight or mass; the forces being considered in a statical point of view only.

The curves have been formed by finding the length of ordinates at convenient distances apart, and tracing a curved line through the points thus obtained.

CROWN WHEEL. A wheel, the teeth of which are at right angles to the plane of the wheel, or parallel to the axis of it. See GEERING.

* CRUCIBLES. The process of reducing an ore to metal is performed in crucibles or pots, of which we employ two distinct kinds; the one is the clay crucible which is free from all carbon, and the other is the plumbago pot. Cast iron crucibles, or retorts of iron, are also used, but not so frequently as to form a particular object for description. Clay crucibles are not, as yet, manufactured in this country. The well-known Hessian crucible is chiefly used. These are perfectly well adapted for most assays, and are cheap and durable. Plumbago crucibles are manufactured in this country to great perfection, and equal to the imported ones. Their use is very limited in the assay. There is no particular necessity of using this crucible at all, because we can line a clay crucible with fine coal dust, which is equal in effect to the plumbago of the black pot. In some instances crucibles of pure coal are necessary; these may be made of a piece of strong charcoal and are then inserted into a Hessian crucible. Generally, a Hessian crucible is filled with finely powdered charcoal, slightly moistened and firmly rammed into it until quite full; a hole is then carved or scraped into the middle, which forms the pot. In other cases, moisten the fine coal dust slightly with gummy water, a solution of starch, oil, salt water, or a weak solution of carbonate of potash or soda. The paste thus formed is in either case rubbed over the inner surface of the clay pot; a lining of about ⅛ of an inch thick is thus formed, which is firmly dried, and forms the coal crucible. The best lining for a crucible is formed of dust from soft coal, such as willow, poplar, or buttonwood coal. The powdered coal is moistened with water and firmly driven in an iron pot which has a form similar to a clay crucible; the cavity is scraped out by means of a knife, and the inner surface finely polished by a glass rod. This lining may be dried in a red heat, provided the caution is taken to fill the crucible with fine dry coal dust and cover it with clay. After burning, it forms a strong pot of a close grain, so that the smallest particle of metal may be detected in it. This coal crucible is inserted in a clay pot and used with it. It is made ¼ and from that to ½ of an inch thick in the sides. Good coal-lined crucibles are indispensable in some assays. Wrought-iron crucibles or retorts are frequently in use. The latter may be made of wrought-iron pipe, bent, and one end stopped up by an iron plug.

Crucibles must be provided with a cover in order to protect the test against the influence of coal and atmospheric air. This cover should have a handle on its upper side, and fit closely to the crucible. In case no regular cover can be obtained, a slab of fire clay, or even a piece of fire brick, may be used as a cover. A good coal, that is, a knotty or spongy piece of coal, may also serve as a cover, but in most cases these throw off splinters which fall into the melting mass and frequently spoil the whole assay. If

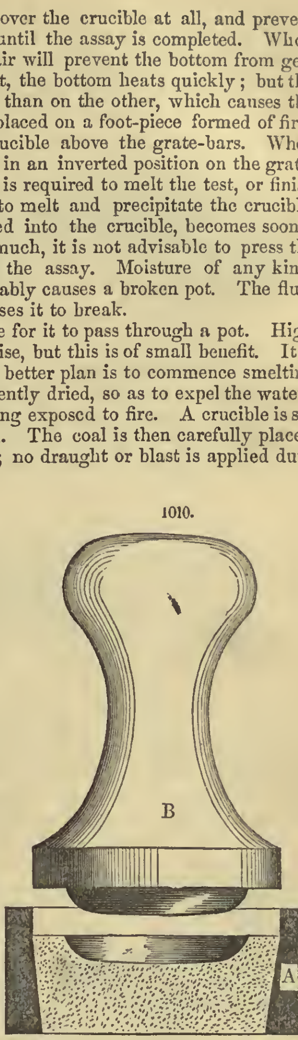
* Overmann's Metallurgy.

the mineral is of such a nature as to boil when heated, we do not cover the crucible at all, and prevent the dropping in of coal by setting around it such coal as will last until the assay is completed. When crucibles are put on the grate-bars of a furnace, the draft of cold air will prevent the bottom from getting hot; if we raise it above the grate-bars and the coal is below it, the bottom heats quickly; but the coal above, in consuming will often sink on one side a little more than on the other, which causes the crucible to incline and spill its contents. A crucible is generally placed on a foot-piece formed of fire-brick. This is from three to four inches high, and elevates the crucible above the grate-bars. When the heat required for the assay is not very high, an old crucible, set in an inverted position on the grate, may serve as a foot-piece. If a very high and a protracted heat is required to melt the test, or finish the assay, the foot-piece must be made of good fire-clay, so as not to melt and precipitate the crucible. The material of the test—that is, ore and fluxes—by being pressed into the crucible, becomes sooner heated. If the test is of such a nature as to melt easily and boil much, it is not advisable to press the mass too strongly, as it may cause the crucible to crack, and spoil the assay. Moisture of any kind, such as water or oil, &c., is objectionable in the crucible; it invariably causes a broken pot. The fluid hardens the mass, which, in expanding more than the crucible, causes it to break.

Crucibles are bad conductors of heat, and it requires a long time for it to pass through a pot. High temperature causes the heat to penetrate a little faster than otherwise, but this is of small benefit. It is therefore of no use to expose a crucible to a high heat at once; the better plan is to commence smelting at a low heat and gradually increase it. All crucibles should be gently dried, so as to expel the water; and any pot which has not been thus dried is liable to crack on being exposed to fire. A crucible is set firmly in the furnace, upon its sole-piece, while the furnace is cold. The coal is then carefully placed around it and the fire kindled, so that the heat may increase slowly; no draught or blast is applied during the first half or three-quarters of an hour.

* CUPEL. Those small flat crucibles in which a part of a metallic alloy is oxidized, and the oxide absorbed by the vessel, are commonly made of white bone-ashes. A variety of materials can be used for the same purpose, but none are superior to bone-ashes, and few cheaper and more readily obtained. A good cupel is a most important instrument in the dry assay. The quantity of precious metal contained in a ton of alloy is often determined by operating upon a few grains of the alloy; and if the cupel is imperfect, the result must be so likewise. For making cupels the bones of sheep, or oxen, or, in very particular cases, the cores of ox-horns, are used; these are broken fine and burned in an open fire of charcoal, and the white ashes resulting from the operation are ground fine and saved for occasional use. It is essential to good success in cupelling, that all carbonaceous matter should be expelled from the bones. The calcining is therefore repeated when any doubt exists as to its having been performed perfectly in the first operation. The bone-ashes must be perfectly white, without a shade of gray when moistened. The burned bones may be crushed in a mortar, or ground in a mill. In all cases they must be converted into a fine powder, which is worked through a fine silk sieve, and is subsequently washed in lukewarm water. The latter operation removes the soluble salts which are in the ashes. It may be repeated to free the powder entirely from such salts, because these always absorb moisture, retain it, and cause the cupel to crack on being exposed to heat. The remaining powder consists chiefly of phosphate of lime, mixed with a little carbonate of lime, and some silicious matter derived from the ashes of the charcoal.

1010.



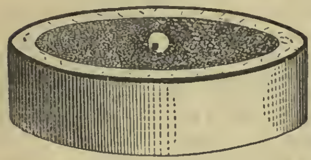
The cupels are formed in a circular mould made of bronze or wrought-iron, or of steel. This apparatus is represented in fig. 1010 in section. The mould A forms a ring, more or less inclined within, nicely turned and smooth; this mould is firmly set on an iron plate, and filled with previously moistened bone-ashes. These are pressed into the mould by an iron ramrod until it is filled. The pestle B is then set upon the surface of the ashes, and driven firmly into it, forming a smooth concavity in the cupel. In driving the pestle with a wooden mallet into the mould, it must be turned around its axis, which will cause the cavity to become smooth. In order to facilitate the latter operation, a little dry bone-ashes is sifted upon the cavity, which causes its surface to be more compact and assume a perfect smoothness. Small cupels, such as those of from ½ inch to two inches diameter, are strong enough when manufactured in this manner. Larger cupels, even those of two inches in diameter, are not strong enough to resist the influence of a great heat without breaking. When this happens, the assay is lost, or at least uncertain. Large cupels are made by filling an iron ring with bone-ashes, as is shown in fig. 1011. Such a ring has the diameter of the cupel, and is from ¾ to one inch high. It is filled with damp ashes, firmly rammed in; and the cavity is scraped out by a knife, and polished by rubbing it smooth with a convex steel button. The iron ring, which may be roughly made, is used so long as it is not burned, and often serves for twenty and more successive cupels and smeltings. Each refining, or assay, requires in all cases a fresh cupel.

The moistening of the ashes for making the cupel is a delicate operation, particularly when they have been dry for some time. The degree of dampness at the time of making the cupel has a marked influence on the result of the operation. If the ashes are too damp the cupel will

* Overmann's Metallurgy.

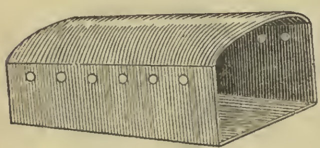
be porous, and liable to absorb metal with the oxides. If the ashes are too dry, the cupel will be close, not sufficiently porous, and work slow; it requires a high heat to imbibe the formed oxides. The best time for making the cupel is when the ashes have been washed with warm water and are thoroughly wet. In this damp state they are exposed to the influence of a warm room, or to the rays of the sun, and constantly stirred to prevent particles becoming too dry. The mass is dried in this manner until it will hardly adhere together when squeezed between the fingers. It is now wrapped in paper and surrounded by a damp cloth, to prevent the evaporation of more moisture. In this state it is employed for making cupels at once. Some manufacturers use farinaceous substances, such as beer or dissolved starch, for glueing the ashes together. When this way of damping the ashes is adopted, the cupels must be exposed to a red heat before they are fit for cupellation. Such admixtures cause the cupels to be porous, and for alloys of gold, silver, and particularly copper, too porous. Good cupels consist of ashes neither too fine nor coarse; fine ashes are required for alloys of gold and silver. In assays on minerals it is necessary to make use of the finest kind of bone-ashes, and use more time in cupelling. All the disadvantages resulting from the use of fine ashes are slow work, more fuel and time; but the assay is always more correct than in cupels made of coarse ashes.

1011.

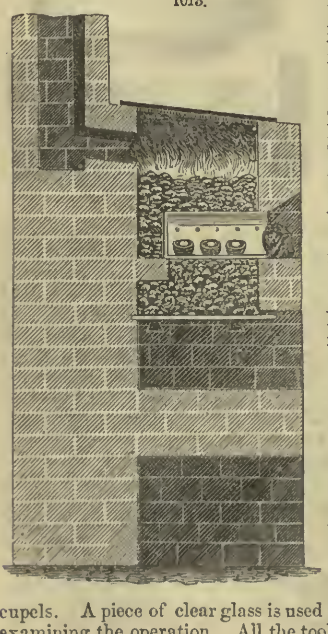


Cupel Furnace. To heat the cupel a furnace of peculiar form is required In some instances it is portable and the fire urged by bellows; for other purposes it is found preferable to employ a stationary furnace. The essential part of a cupel furnace is the muffle. This is a box in the form of a travelling trunk, one end of which is open. In fig. 1012, a muffle is represented. It is a clay trunk of from 10 to 15 inches in length, 5 to 7 inches in width and height. The size is determined according to circumstances. A small muffle of 10 by 5 inches is for small assays all sufficient. In the two sides of the muffle, a series of round apertures is formed to cause a draught of fresh air to pass through the interior. The muffle is made of fire-clay, about half an inch thick and well backed before it is walled in. In large cities muffles may be bought ready made in potters' warehouses. The vapors and oxide of lead which are the result of the cupelling operation, are very severe on the clay of the muffle, and the bottom of it suffers more than any other part; for this reason, the bottom is covered sometimes with bone ashes or common ashes. This is however of little use, for the lead will still reach the clay. It also causes the cupel to heat slowly. When a bottom is eaten through, the muffle is of no farther use and must be replaced by a new one. In fig. 1013 a furnace is represented in which the muffle is walled in. In this instance the whole of the muffle is surrounded by hot coal; it is in the centre of the heat; its bottom is about five inches above the grate-bars, so that coals which come down on both sides may fill the space below. The bottom of the muffle need not be so hot as the top. The oxidation and evaporation of lead is caused by reflection from the top of the muffle. One end of the muffle rests in the front brick wall, and the other is supported by a bracket of brick in the opposite wall. The bottom must be perfectly horizontal in order to afford the cupels a horizontal position. The fire is kindled below the muffle, and in the first stages of the operation, some few pieces of charcoal are laid at the mouth of the muffle, in order to heat it quickly and uniformly. This furnace, with its muffle, is also used for roasting and calcining ore.

1012.



1013.



When a muffle cannot be obtained, a large crucible may be set in a furnace and serve the same purpose; or if no cupel furnace can be had, a cupellation may be performed in a crucible, in the bottom of which a hole has been pierced. The cupel is set on a level with its metal in the crucible, and the latter in the smelting furnace, so that air may be drawn in from below through its bottom, and pass around the cupel, the top being uncovered. It requires some attention to prevent the crucible from falling on one side, in consequence of the unequal consumption of fuel in the furnace. The pierced crucible may also be posted on a pierced sole-piece. This mode of working keeps the cupel rather cool. In a charcoal fire, a sole-piece is of great utility; in a coke fire, a little attention will be equivalent to the sole-piece, and in an anthracite fire there is no difficulty whatever in cupelling in this manner.

The instruments used in cupelling are a pair of small tongs, some hooks of iron wire, and at times bent glass rods, also a pair of light tongs and an iron spoon for bringing the lead upon the cupels. A piece of clear glass is used to protect the eye against the radiating heat from the muffle while examining the operation. All the tools should be provided with wooden handles.

CUTTING AND CARVING MACHINERY. *Machinery and Apparatus for Cutting and Carving Substances to be applied for Inlaying and other purposes.*—This invention consists in certain improved constructions or arrangements of machinery, having a revolving cutter, by means of which, in conjunction with a moveable table, tablets of wood and other materials can be cut away, carved, countersunk, and perforated, in various ornamental forms, with great facility, for the production of inlaid devices, gothic tracery work, and other kinds of ornaments hitherto usually wrought by hand.

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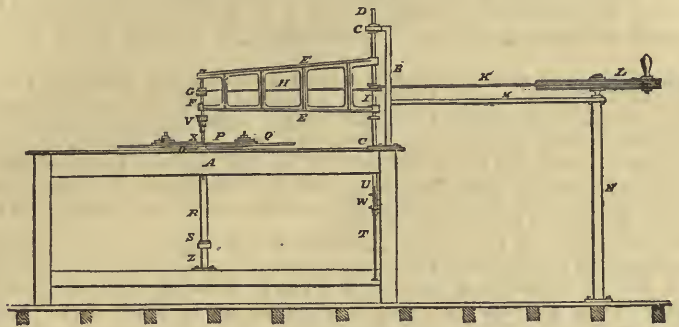

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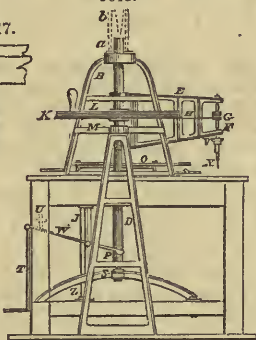

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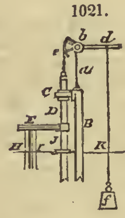

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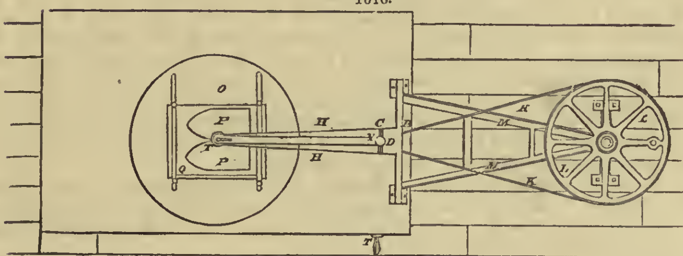


Fig. 1014 represents a side elevation; Fig. 1015, an end elevation; and Fig. 1016, a horizontal view of the machinery. A A is a bench or table, for supporting the several parts of the machine; B B is a standard or bracket-frame, firmly fixed to the said bench; which frame is provided with plummer-blocks and bearings C C, to receive a spindle D. E is a forked frame or swinging arm, firmly fixed upon the spindle D; and the other end of the arm E is furnished with suitable bearings, which carry, in a vertical position, a spindle F. The lower end of this spindle F is formed to receive a chuck V, or other suitable contrivance, for attaching and holding securely the tool, drill, or cutter X, or such other cutter as may be required; and upon the spindle F, near its upper end, is fixed a conical pulley G, having grooves of different diameters, for the purpose of determining the velocity with which the spindle shall be made to revolve. This pulley is designed to receive an endless band or cord H, which passes round the lower part of a similar pulley I, running loosely upon the spindle D; the upper groove of the pulley I is made to receive another endless band or cord K, that passes around a wheel or drum L, supported by a standard or frame N, which is connected by a similar frame M, to the standard B; but the band K may be driven by any other means. O is a horizontal moveable table, mounted upon a vertical shaft R, which passes through the bench A; its lower end being supported by, and turning freely upon a step or bearing S, in the arch Z, fixed to the framing of the bench. The tablet or slab of wood, or other material intended to be wrought by the cutter X, is to be placed upon the turning-table as at P, and made fast thereon by screwed clamps. At the left-hand end of the bench A, there

is a vertical bar J made fast to the wood framing, in which there is a fulcrum-pin for the lever W to turn upon; one end of this lever W is formed into a concave socket to receive, as a step, the lower end of the spindle D before mentioned, and the other end of the lever is connected by a joint with a treadle-rod T. This treadle-rod and lever are for the purpose of raising, when required, the spindle D, with the forked frame E, carrying the drill. U is an adjustable screw set in the leg of the bench as a stop to the lever, intended to regulate the descent of the spindle D with the frame E, in order that the cutter X shall not penetrate deeper into the material or substance P than may be desired.

Fig. 1021, and the part dotted in Fig. 1015, represent another arrangement for raising and lowering the spindle D with the forked frame and drill, instead of the lever and treadle-rod before described: this arrangement is used when the carving of variable relief, such as foliage, figures, &c., is required to be executed.

Upon any convenient part of the standard B is fixed a frame *a*, with bearings *b b* to receive and support the axle of a quadrant *c*, which has a lever *d* attached to its centre. From the periphery of the quadrant *c* is suspended by a chain *e*, or other suitable contrivance, the spindle D, carrying the forked frame E with the drill. To the lever *d* a weight *f* is suspended by a rod, or other convenient means, hung in any of the notches provided in the lever for that purpose; which weighted rod acts as a counter-balance to the spindle D and the several parts attached thereto, thus enabling the cutter X to be raised or lowered with the greatest facility and precision; all the other parts of the machine, and their action, being the same as hereinbefore described.

Fig. 1017 is an elevation, and Fig. 1018 an under-side or end view, of a tool or cutter for cutting or carving a semi-circular or quarter-round hollow, for mouldings, gothic tracery, &c.; Fig. 1019 is an elevation, and Fig. 1020 an under-side or end view, of a tool or cutter for cutting or carving a bed and fillet, or astragal. These are only two examples of cutters, but of course a great variety may be employed, and these must depend upon the form of the edge of the recess intended to be cut or formed; as any and every variety of rounds and hollows, ovolos, ogees, &c., separately or combined, may be executed, not only in straight lengths, but to the form of any regular or irregular curve that may be desired.

The mode of cutting or carving with this machine is as follows:—Upon the revolving table O, the tablet, slab, or piece of wood, or other material P to be cut or carved, is fixed; and on its upper surface, when desired, is placed a template or pattern Q, (formed of iron, brass, or other approved material,) of the design required to be cut or carved; and the two are firmly held upon the table O, by cramps or cramping-bars, as shown. Motion being given by any convenient power to the wheel or drum L, or communicated by any other means to the band or cord K, the pulley I will be made to turn rapidly upon the spindle D; by which means the band or cord H passed round the pulley G will cause the spindle F carrying the cutter X to revolve with great speed, the velocity of the cutter being determined by the proportions which the diameters of the pulleys G and I bear to each other, and the speed of the driving power. The cutter X being set to the depth of cut required by adjusting the stop U, the workman passes down the treadle-rod T with his foot, which causes the lever W to raise the spindle D with the cutter X, and the several parts attached thereto: thus the forked arm E is raised, and being moved around the cutter X, may be passed over the tablet P in an arc; at the same time the moveable table O must be turned, so that the cutter may be perpendicularly pendent over the part of the tablet where the work is to commence. The revolving cutter X is then let down, by removing the pressure from the treadle-rod T, and it immediately penetrates into the tablet. The form in which the cutter moves over the tablet is now to be determined by guiding the shaft of the cutter against the edges of the template or pattern; the table O, with the tablet P upon it, being moved at the same time, in order to keep the edge of the template always close to the shaft of the cutter. By thus moving the swinging-frame E and the table O, various arcs of circles that are constantly tangental to each other may be traced upon the tablet under operation; thereby enabling every possible variety of regular and irregular, curved, and straight forms to be cut or carved in the material acted upon; and this combined or simultaneous action forms the principal novelty of the invention.

The patentee claims the combination and application of the several parts as herein shown and described, and any variation of that combination or application for effecting the principle of his invention; provided the swinging-frame which carries the cutter, and also the table on which the article to be wrought is placed, have both the means of circular motion.

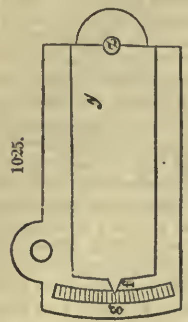
CUTTING-ENGINE. Mr. Joseph Gaume, of Cincinnati, Hamilton County, Ohio, has invented a new and useful improvement in the Cutting-Engine, or machine for dividing and cutting the teeth of cog-wheels. In the accompanying engravings, Fig. 1022 is a plan, Fig. 1023 a side elevation, and Fig. 1024 a front view. The same letters indicate like parts in all the figures.

The leading object of this invention is to adapt the common lathe, by the addition of certain parts, to the cutting of cog-wheels, chiefly for the use of small shops and manufactories where a lathe and cutting-engine are only required occasionally. And the nature of the first part of his invention consists in adding to a lathe, and in combination with the mandrel thereof, a puppet made in two parts for carrying the cutter, the lower half to be attached in the usual manner to the bench, and connected with the upper one by an inclined plane, that the upper part may slide on the lower one at an angle of forty-five or any other number of degrees, for the purpose of carrying the cutter or curr over the wheel in the operation of cutting the cogs of bevel-wheels. The second part of his invention consists in combining with this puppet the cutter-frame, which carries the spindle of the cutter or curr by means of an adjustable horizontal slide, on which the cutter-frame moves to and fro to carry the cutter over the wheel in which the cogs are to be cut; the said slide being a plate with dove-tail or other formed edges, embraced by or embracing the cutter-frame, and attached at one end by a fixed bolt to the top plate of the puppet, and at the other by a screw bolt that passes through a curved slot, whereby the cutter-frame may be made to carry the cutter in its horizontal motion diagonally with the axis of the mandrel for the cutting of diagonal cogs: the spindle of the cutter or curr having its bearings in an adjustable slide

that moves at right angles to the mandrel, to bring the cutter over the axis of the mandrel, (the bed of the slide being connected with a vertical side in the cutter-frame to adapt the cutter to wheels of different diameters,) by means of a fixed bolt on one side and a screw-bolt passing through a curved slot on the other, that the axis of the cutter may be placed at any angle with a vertical line. The third part of the invention relates to the method of dividing the cogs, and consists in placing the index-wheel on a slide, that it may be adjusted to a wheel of any desired number of cogs on an arbor that communicates by a screw or its equivalent to the mandrel which carries the wheel to be cut, so that, by merely changing the wheel on this arbor, a single division index may be used for the cutting of any desired number of cogs. The fourth part of the invention consists in combining the dividing apparatus with the mandrel of a lathe, by means of cogs on the pulley of the mandrel or on the mandrel, the dividing apparatus being so arranged that it can be thrown in and out of geer. In the accompanying drawings *a* represents the bench of the lathe, and C the mandrel with its set of cone pulleys *c*, the face of the larger one of which is a crown cog-wheel *d*, the cogs of which engage with the threads of an endless screw on arbor *e*: the threads of the screw are shown by dotted lines in the plan, Fig. 1022. One end of the arbor runs on the point of a pivot-screw *f*, and the other has a long journal that runs in a box in a standard *g* attached to the bench or the puppet head of the mandrel, so that when the rear end is liberated from the pivot-screw, the arbor can be moved far enough in the standard *g* to carry the ends of the screw out of the cogs of the crown-wheel, that the mandrel may be used for turning the cog-wheel: in this way the wheel can be made with great accuracy, for it is turned and cut on the same mandrel, and therefore there is no danger of not having the wheel properly centered. When the wheel is to be cut, the arbor *e* is properly mounted, and its outer end is adapted by a collar and nut to receive a spur-wheel *j* of any desired number of cogs, which take into the cogs of the wheel K, one face of which is provided with the division plate or index *b*, and the other end with a handle *m* for turning it. This wheel is fitted to and turns on a stud-pin *n*, projecting from plate *o*, that slides on an arm *p* of the standard *g*, that it may be set to the proper pitch line of a wheel of any desired size on the arbor *e*, and there held by a screw *q*. A spring point or catch *r* is used to catch in the notches of the index or division plate *b*.

From the foregoing it will be seen that with any given size of wheel on the arbor *e*, the number of cogs to be cut may be varied by the motions of the dividing or index wheel, as in the ordinary dividing-engine, and that, by changing the wheel on the arbor *e*, any variation can be given to these divisions. The wheel having been turned and the dividing apparatus put in connection, the centering puppet head *s* of the lathe is thrown back, and the extra puppet *t* is secured in place on the bench. This puppet is made in two parts, (t *t*,) connected together by a dove-tail or other slide *u* at an angle of 45°, or any other number of degrees with the plane of the bench. The lower half *t* is secured to the bench, and the other (t) can be made to slide on it by means of a handle or lever *v* that turns on a fulcrum-pin *w* attached to the lower half, and connected with the upper half by a pin X that passes through a slotted hole in a well-known manner. The top plate of the upper half is in a plane parallel with the mandrel, and has a dove-tail slide *y* connected with it at the forward end by a fixed bolt *z*, (see Fig. 1025, which is a plain view of this part,) and at the other end by a screw bolt (a) that passes through a curved slot (see the dotted line) in the top plate, so that any horizontal inclination desired may be given to this slide which is embraced by the bottom plate H of the cutter-frame, (c,) and which can be made to slide thereon by a handle or lever (d) that turns on a fulcrum-pin attached to the puppet and connected with the cutter-frame by a joint-link, (e,) so that by the motion of this lever the attendant carries the cutter to and fro horizontally over the edge of the wheel to be cut, for cutting spur cogs in a direction parallel with the axis of the mandrel, or inclined therewith as the slide may be set, to be indicated by a pointer (f) on the cutter-frame, and an index (g) on the top plate of the puppet. But when the machine is used for cutting the cogs on bevel-wheels, then the cutter-frame is carried by sliding the upper part (t) of the puppet head on the lower part Fig. 1025; the inclination of this slide determining the bevel of the cogs cut. The forward part of the cutter-frame has a plate, (h,) that slides in it vertically by means of a screw, (b,) to adapt the cutter to any desired diameter of wheel to be cut; to this is connected another plate (j) that turns on a bolt, and further secured by a screw-bolt (k) that passes through a curved slot, (l,) by means of which the plate (j) may be turned on the fixed bolt as a centre to give any desired inclination to the axis of the cutter; and this last-named plate is provided with dove-tail ways in which slides the cutter-carrier (m,) which is a frame in which are the bearings of the spindle (n) of the cutter, (o,) so that this may be regulated endwise by a set screw (p.) The cutter is rotated by a belt (q) that passes from any first mover over a pulley (r) on the spindle. From the foregoing it will be seen that the cutter can be adjusted in any direction relatively to the axis of the mandrel that carries the wheel to be cut, and that, by means of one of the handles or levers, the cutter-frame can be moved to and fro to cut the cogs by sliding the cutter-carriage on the puppet in a horizontal plane parallel with the axis of the mandrel, which, by the adjustment of the ways or slide on the puppet, may be adjusted to move in a vertical plane projected from the axis of the mandrel or at any inclination therewith to cut oblique cogs; or, by means of the other handle, that the cutter-frame may be made to move with the upper part of the puppet on an inclined plane to cut the cogs of bevel cog-wheels. It will be obvious, from the above, that the plan of the junction of the two halves of the puppet may be made at any inclination desired to suit the bevel of the wheel intended to be cut.

What he claims as his invention and has secured by letters patent, is making the puppet which carries the cutter-frame in two parts, separated by an inclined plane, that one may slide on the other for cutting the cogs of bevel-wheels, in combination with the cutter-frame that slides thereon; and also the cutter-frame and double puppet combined together in combination with the mandrel of the lathe. He also claims the method of adapting the index or division plate that has but one set of divisions, to any division of cogs desired to be cut, by means of shifting the wheel on the arbor that communicates motion to the mandrel, in combination with the sliding connection of the index or division wheel, whereby numerous divisions on the index plate are avoided. And further, he claims the dividing apparatus in combination with the mandrel of a lathe by means of the cog-wheel and pulleys put on one end of the



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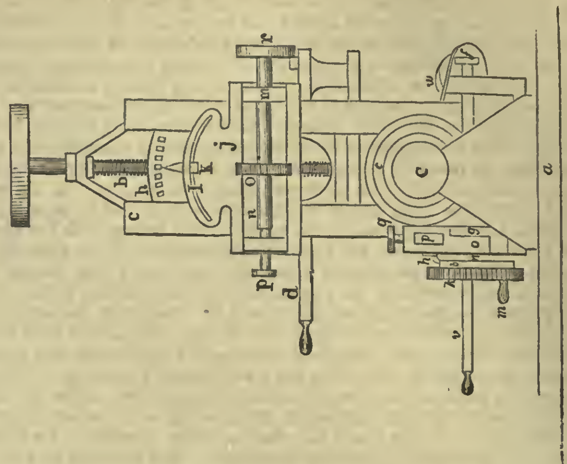

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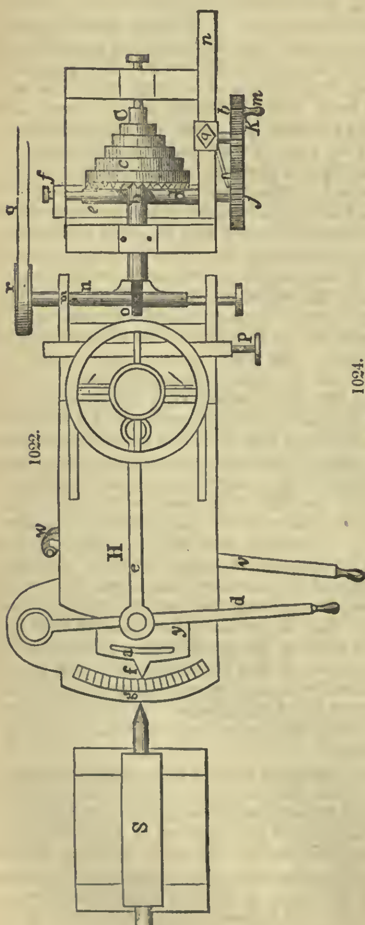

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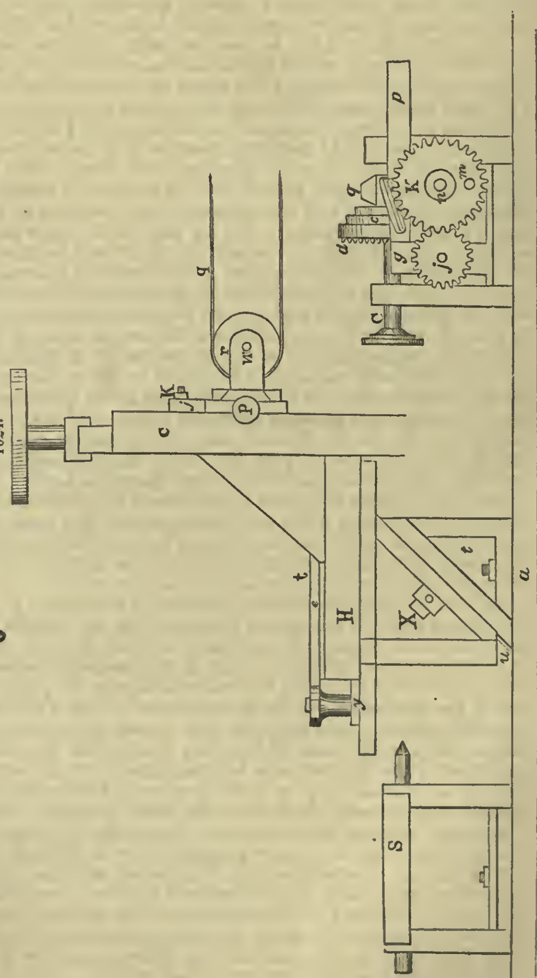


1024.

same mandrel, whereby the wheels to be cut can be turned and cut on the same mandrel without being removed therefrom to insure good work, and whereby also the turning-lathe may be used for a cutting engine.

This machine may be composed either of a single lathe, or of a complicated one, of any desired dimensions, and nothing need be added to it but a side-coupling, to form the division.

First. Its advantages are: turning the wheel on its points; it is thus cut on these same points, with the axis, the length which may be placed on the lathe; likewise, by turning the wheel on the flat side, the hole in the centre and the circumference are cut without its being removed.

Second. This machine can cut a wheel on the circumference obliquely, to the right or left, with any desired inclination; and also the same with regard to the wheel on the side.

Third. The wheel can be cut at an angle of forty-five degrees. This machine can take the place of, and even offers more advantages than the "Great Platform." It can be constructed of any dimension, always being able to cut the wheel which can be turned on the lathe, even should it be fifteen feet in diameter. This machine can be adapted to a lathe placed upon a wooden bench, with only one hundred and fifty pounds additional weight of castings. This cutting machine may be obtained, with all the above-mentioned advantages, from one inch in diameter to two feet. The cast-iron lathe offers more solidity, and with a little additional expense. The division extends to all numbers with the greatest precision.

CUTTING AND PUNCHING MACHINE. See Punching and Cutting Machine.

CUTTING TOOLS, *general remarks upon.* Cutting tools may be included in three groups, namely, Paring Tools, Scraping Tools, and Shearing Tools.

First. Paring or splitting tools, with thin edges, the angles of which do not exceed sixty degrees; one plane of the edge being nearly coincident with the plane of the work produced, (or with the tangent, in circular work.) These tools remove the fibres principally in the direction of their length, or longitudinally; and they produce large coarse chips or shavings, by acting like the common wedge applied as a mechanical power.

Secondly. Scraping tools with thick edges, that measure from sixty to one hundred and twenty degrees. The planes of the edges form nearly equal angles with the surface produced; or else the one plane is nearly or quite perpendicular to the face of the work, (or becomes as a radius to the circle.) These tools remove the fibres in all directions with nearly equal facility, and they produce fine dust-like shavings by acting superficially.

Thirdly. Shearing or separating tools, with edges of from sixty to ninety degrees, generally duplex, and then applied on opposite sides of the substances; one plane of each tool, or of the single tool, coincident with the plane produced.

In explanation of these views, the diagram, Fig. 1026, is supposed to represent seven different tools, the bevels or edges of which are all at the angle of sixty degrees; this may be considered as the medium angle of the paring, scraping, and shearing tools.

The cutting and scraping tools are supposed to be moving from A to B, which line represents the face of the work; or the tools may be considered to be at rest, and the work to be moving from B to A.

Or, in turning, the tool may be supposed to remain fixed, and the circle to represent the moving surface of the work; one plane of the tool then becomes a tangent or radius.

The shearing tools, if in pairs, are proceeding towards each other on the line C D, whilst A B still represents the face of the work. The single tools act on the same principle, but the body of the material, or the surface of the bench or support, supplies the resistance otherwise offered by the second tool.

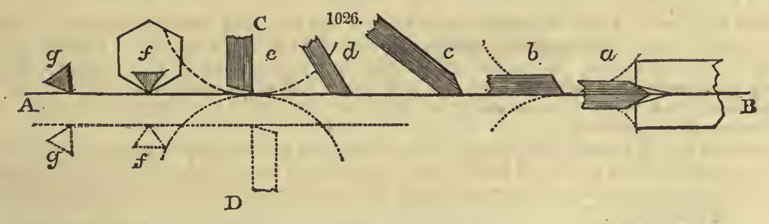
The tools *a c f* are bevelled or chamfered on both sides, the others from one side only; in these latter, the general face of the tool forms the second side of the angle, and allowing for exaggeration, both as to excess and deficiency, the diagram may be considered to represent the edges of the following tools.

[*a b c d*, Splitting and Paring Tools, proceeding from A to B.]

a, The axe, or the cleaver for splitting.

b, The side hatchet, adze, paring and drawing knives, paring chisels and gouges, the razor, penknife, spokeshave, the engraver's graver, and most of the engineer's cutting, turning, and planing tools for metal.

1026.



c, The turning chisel for soft wood, the chipping chisels for iron, stone, &c.

d, The joiner's chisels and carving tools, used with the bevels downwards, the joiner's planes, the cross-cut chisel for metal, and some other metal tools.

[*e f*, Scraping Tools, proceeding from A to B.]

e, When single, the scraping tools for turning the hardwoods, ivory, and brass, the hand-plane for metal; and when multiplied, the various saws and files.

f, When single, a triangular scraper for metal; and when multiplied, the cross-cut saw for wood, and also polygonal broaches or rimers with any number of sides, for metal.

[*e f*, Shearing Tools, proceeding from C to D.]

e, When duplex, shears with edges from eighty to ninety degrees, commencing with delicate lace

scissors for single threads, and ending with the engineer's shears for cutting iron bars and plates upwards of one inch thick; also duplex punches with rectangular edges, for punching engines and fly-presses.

e, When single, the carpenter's firmer and mortise-chisels, the paring-knife moving on a hinge, and cutting punches for gun-wadding and thin materials.

f, When duplex, common nippers for wire; more generally, however, the blades are inclined so that one bevel of each blade lies in one and the same plane, and which is vertical to A B, as at *g g*.

f, When single, the smith's cutting-off chisel.

In practice, the tools differ from the constant angle of sixty degrees, assumed in the diagram for the convenience of explanation, as the angles of all tools are determined by the hardness and the peculiarity of fibre or structure of the several substances upon which they are employed. The woods and soft fibrous materials require more acute angles than the metals and hard bodies; and the greater or less degree of violence to which the tools are subjected, greatly influences likewise the angles adopted for them.

Thus, under the guidance of a little mechanism, the thin edge of a razor, which is sharpened at an angle of about 15 degrees, is used to cut minute slices or sections of woods, in all directions of the grain, for the purpose of the microscope. But the carpenter and others require more expeditious practice, and the first change is to thicken the edges of the tools to range from about 20 to 45 degrees, to meet the rough usage to which they are then exposed, whether arising from the knots and hard places in the woods or the violence applied.

In tools for iron and steel from 60 to 70 will be found a very common angle, in those for brass 80 to 90, in hexagonal broaches for metal it increases to 120, and in the octagonal broach sometimes employed the angle is still greater; in the circular broach required by clock and watch makers, the angle disappears and the tool ceases either to cut or scrape, it resolves itself into an instrument acting by pressure, or becomes a burnisher.

To a certain extent, every different material may be considered to demand tools of a particular angle, and again the angle is somewhat modified by the specific mode of employment: these conditions jointly determine the practical angles suited to every case, or the angles of greatest economy or most productive effect.

The diagram shows that, independently of the measure of the angle of the tool, we have to consider its position as regards the surface of the work, the broad distinction being that, in the paring tools, the one face of the wedge or tool is applied nearly parallel with the face of the work; and in the scraping tools, it is applied nearly at right angles, as explained in the foregoing definitions. Indeed the paring tools, if left to themselves, will in some cases assume the position named; thus, for example, if we place a penknife at an elevated angle upon a cedar pencil, and attempt to carry it along as a carpenter's plane, the penknife, if held stiffly, will follow the line of its lower side and dig into the wood; but if it be held slenderly, it will swing round in the hand until its blade lies flat on the pencil, and it will even require a little twisting or raising to cause it to penetrate the wood at all. This disposition appears to be equally true in the thin edges of the penknife or razor, and in the thick edges of the strong paring tools for metal.

The action of a cutting tool in motion is two-fold. The moving force is first exerted on the point of the wedge, to sever or divide the substance particle from particle; the *cohesion of the mass* now directly opposes the entry of the tool, and keeps it back. But the primary motion impressed on the tool having severed a shaving, proceeds to bend or curl it out of the way; the shaving ascends the slope of the wedge, and the *elasticity of the shaving* confines the tool in the cleft, presses it against the lower side, disposes it to pursue that line, and therefore to dig into the substance.

The Forms and Motions of Tools, as regards the production of Lines, Superficies, and Solids.—The principles of action of all cutting tools, and of some others, whether guided by hand or by machinery, resolve themselves into the simple condition, that the work is the combined copy of the form of the tool, and of the motion employed. Or in other words, that we exactly put into practice the geometrical definitions employed to convey to us the primary ideas of lines, superficies, and solids; namely, that the line results from the motion of a point, the superficies from the motion of a line, and the solid from the motion of a superficies.

It therefore follows, as will be shown, that when the tool is a point having no measurable magnitude, that two motions must be impressed upon it, one equivalent to the breadth, and another equivalent to the length of the superficies. When the tool is wide, so as to represent the one dimension of the superficies, say its breadth, then only one motion is to be impressed, say a motion equivalent to the length of the superficies; and these two are either rectilinear or curvilinear, accordingly as straight or curved superficies are to be produced.

To illustrate this in a more familiar way than by the ideal mathematical conceptions—that a point is without magnitude, a line is without breadth, and a superficies without thickness—we will suppose these to be materialized, and to become pieces of wood, and that the several results are formed through their agency on soft clay.

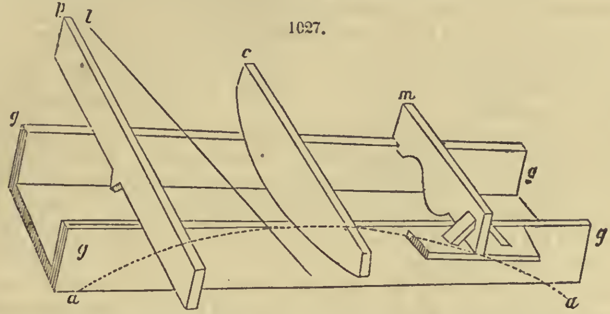
Thus supposing *g g* to be two boards, the edges of which are parallel and exactly in one plane, and that the interval between them is filled with clay; by sliding the board *p* along the edges of *g g*, the point in *p* would produce a line, and if so many lines were ploughed that every part of the clay were acted upon by the point, a level surface would at length result. The line *l*, such as a string or wire, carried along *g g*, would at one process reduce the clay to the level of the edges of the box.

Either the point or the line might be applied in any direction whatever, and still they would equally produce the plane, provided that every part of the material were acted upon; and this, because the section of a plane is everywhere a right line, and which conditions are fulfilled in the elementary apparatus, as the edges of *g g* are straight and give in every case the longitudinal guide, and with *l* the second line is formed at once, either with a string, a wire, or a straight board; but in *p* the point

requires a second or transverse guide, and which is furnished by the straight parts of the board p rubbing on the edges of $g\,g$, and therefore the point obtains both a longitudinal and a transverse guide, which were stated to be essential.

The board c, with a circular edge, and m, with a moulding, would respectively produce circular and moulded pieces, which would be straight in point of length in virtue of $g\,g$ the line of motion, and curved in width in virtue of c or m the lines of the tools. But now c and m must always advance parallel with their starting positions, or the width of the moulding would vary; and this is true, whenever curved guides or curved tools are employed, as the angular relation of the tool must be then constantly maintained, which it is supposed to be by the external piece or guide attached to m.

1027.



Supposing $g\,g$ each to have circular edges, as represented by the dotted arc $a\,a$, or to be curved into any arbitrary moulding, the same boards p, l, c, m would produce results of the former transverse sections, but the clay would in each case present, longitudinally, the curved figure of the curved longitudinal boards $a\,a$; here also the line of the tool and the line of the motion would obtain in the result.

If, to carry out the supposition, we conceive the board $a\,a$ to be continued until it produced the entire circle, we should obtain a cylinder at one single sweep, if the wire l were carried round at right angles to $a\,a$. But to produce the same result with the point p, it must be done either by sweeping it round to make circular furrows very near together, or by traversing the point from side to side, to make a multitude of contiguous lines parallel with the axis of the cylinder. In either case we should apply the point to every part of the surface of the cylinder, which is the object to be obtained, as we copy the circle of $a\,a$ (which is supposed to be complete) and the line l, or the transverse motion of p, which is equivalent to a line.

But it is obvious that, in every case referred to, there is the choice of moving either the clay or the tool, without variation in the effect. If in respect to the circular guide $a\,a$, we set the clay to rotate upon its centre, we should produce all the results without the necessity for the guide-boards $a\,a$, as the axis being fixed, and the tool also fixed, the distance from the circumference to the centre would be everywhere alike, and we should obtain the condition of the circle by *motion alone*, instead of by the *guide;* and such, in effect, is turning.

An every-day example of this identical supposition is seen in the potter's wheel; and the potter also, instead of always describing the lines of his works with his hands, as in sketching, occasionally resorts to curved boards or templets, as for making the mouldings for the base of a column, or any other circular ornament. But here, as also in ordinary turning, we have choice either to employ a figured tool, or to impress on a pointed tool a path identical with the one section; for example, the sphere is turned either by a semicircular tool applied parallel with the axis, or else by sweeping a narrow or pointed tool around the sphere in the same semicircular path.

Having shown that in every case the superficies is a copy of the tool and of the one motion, or of the point and the two motions, it will be easily conceived that the numerous superficies and solids, emanating from the diagonal, spiral, oval, cycloid, epicycloid, and other acknowledged lines, which are mostly themselves the compositions of right lines and of circles, may be often mechanically produced in three different ways.

First, by the employment of tools figured to the various shapes, and used with only one motion or traverse; secondly, by the use of figured guides, *cams*, or *shaper-plates*, by which the motion is constrained, just the same as p makes a right or a curved line, in virtue of its straight or curved guide; and thirdly, by the employment of a point actuated by two motions, by the composition of which most geometric lines are expressed.

Thus when *uniform* motions are employed, two rectilinear motions produce a diagonal to themselves; one circular and one continued right-line motion, give the spiral, the screw, and the cycloid: also if, during *one* circular revolution, either the circle or the point make *one* oscillation in a right line, we obtain the oval; by two circular movements we obtain the epicycloid, by three motions the compound or double epicycloid, and so on. And when one or both of the rectilinear or circular generating motions are *variable* as to velocity, we obtain many different kinds of curves, as the parabola, hyperbola, and others; and thence the solids, arising from the revolutions of some of these curves upon an axis.

We produce the practical *composition* of any two lines or movements, whether regular or irregular, by impressing these movements on the opposite extremities of an inflexible line or rod; from which rod we obtain a compounded *line* if we trace the motion of a point inserted in any part of the rod, and we obtain a compounded *superficies* if we copy the motion of the entire line. This may need explanation.

Supposing that in Fig. 1027, the back guide $g\,g$ to remain a straight line, the front to become the

circular arc *a a*, the board *p* being now traversed in contact both with the straight and curved edges, the point *p* would describe a line if it were close against the line *g g*, or an arc if close against the arc *a a;* midway it would describe an arc of about half the original curvature. On the other hand, the line *b* would cut off the clay in a superficies, possessing at the three parts these same conditions, and merging gradually from the right line to the arc *a a*.

But a similar composition of the two lines or motions would occur, were the lines *g g*, *a a* to be exchanged for any others, similar or dissimilar, parallel or oblique, or irregular in two directions; and in mechanical practice we combine, in like manner, two motions to produce a compound line or a compound superficies. Indeed in many cases there is no alternative but to impart to two edges *g a* of a block the marginal outlines of the superficies, and then, generally by *hand-labor*, to reduce all the intermediate portions under the guidance of a straight edge applied at short intervals upon the two edges, which thus become compounded or melted together in the superficies. Numbers of irregular surfaces can be produced by this mode alone.

In fine, in mechanical processes, we translate the mathematical *conceptions* of the rectilinear, circular, and mixed motions of points and lines, into the mechanical *realities* of rectilinear, circular, and mixed motions of pointed or linear tools.

It is not imperative, however, that the tools should have but one fixed point or edge, as without change of principle a succession of similar points may be arranged in a circle, to constitute a revolving cutter, which by its motions will continually present a new point, and multiply the rapidity of the effect. In most cases, the introduction of a tool with a figured outline, cancels the necessity for the means otherwise required to generate such figured line by the motion of a point; and a tool with a figured superficies, cancels also the remaining motion required to produce the superficies, and the tool is simply impressed as a stamp or die.

In tracing the method of applying these theoretical views to the explanation of the general employment of cutting tools, or the practice of the workshop, we may safely abandon all apprehension of complexity, notwithstanding the almost boundless variety of the elements of machinery, and other works of cutting tools. For although all the regular figures and solids referred to are in reality met with, besides a still greater number of others of an irregular or arbitrary character, still by far the greater majority of pieces resolve themselves into very few and simple parts, namely, solids with plane superficies, such as *prisms*, *pyramids*, and *wedges*, and solids with circular superficies, such as *cylinders*, *cones*, and *spheres*. These are frequently, as it were, strung together in groups, either in their entire or dissected states; but as they are only wrought one surface at a time, the whole inquiry may be considered to resolve itself into the production of superficies.

The *guide principle* is to be traced in most of our tools. In the joiner's plane it exists in the form of the stock or sole of the plane, which commonly possesses the same superficies as it is desired to produce. For instance, the carpenter's plane used for flat surfaces is itself flat, both in length and width, and therefore furnishes a double guide. The flat file is somewhat under the same circumstances, but as it cuts at every part of its surface, from thousands of points being grouped together, it is more treacherous than the plane as regards the surface from which it derives its guidance, and from this and other reasons it is far more difficult to manage than the carpenter's plane.

In many other cases the cutting instrument and the guide are entirely detached; this is strictly the case in ordinary turning, in which the circular guide is given by the revolution of the lathe mandrel which carries the work, the surface of which becomes the copy of the tool, or of the motion impressed upon the tool, either by the hand of the workman under the guidance of his eye alone, or by appropriate mechanism.

When the lathe is employed under the most advantageous circumstances to produce the various geometrical solids or figures, the tool is placed under the guidance of a ruler, or rather of a slide, by which its path is strictly limited to a rectilinear motion. Thus, for a cylinder the slide is placed exactly parallel with the rotary axis of the mandrel, and for a plain flat surface the tool is moved on a slide at right angles to the axis. Generally two slides fixed in these positions are attached to the lathe to carry and guide the tool, the machine being known as the sliding-rest; but mostly the one slide only is used as a traversing or directional slide for guiding the tool, the other as an adjusting or position slide for regulating the penetration of the tool into the work.

Sometimes the two slides are moved simultaneously for the production of cones, but more generally the one slide is placed oblique and used alone. The lathe is employed with great effect in producing plane surfaces, but the more modern engine, the planing-machine, the offspring of the slide or traversing lathe recently adverted to, is now also very much employed for all kinds of rectilinear works.

The planing-machine being intended principally for rectilinear solids of all kinds, its movements are all rectilinear, and these are in general restricted to three, which are in the same relation to each other as the sides of a cube; namely, two are horizontal and at right angles to each other, and the third is vertical, and therefore perpendicular to the other two. The general outline of the machine will be conceived by imagining a horizontal railway to take the place of the revolving axis of the lathe, and the slide-rest of the lathe to be fixed vertically against the face of a bridge stretching over the railway.

In the general structure of this most invaluable machine, the railway is the cutting slide, upon which the work is slid to and fro. For producing a horizontal surface, the horizontal slide is employed for traversing the tool across the face of the work, which is thus reduced by ploughing a series of parallel grooves, not exceeding in distance the width of the pointed tool, so that first the line, and then the surface arise, exactly as in the geometrical suppositions. For vertical planes, the vertical is the traversing slide, the horizontal, the adjusting; and for oblique planes, the vertical slide is swivelled round to the assigned angle, the imaginary railway being employed in all cases to give the cutting motion.

When we examine into almost any machine employed in cutting, it will be found that the end to be obtained is always a superficies, either plane or curved, and which superficies reduced to its elementary condition, presents length and breadth.

When therefore we have put on one side the mechanism required for connecting and disconnecting the engine with the prime mover, whether animal, steam, or other power, it will be found that when the superficies is produced by a pointed tool, the primary motions resolve themselves into two, which may be considered representative of length and breadth. The velocity of the one primary motion is suited to the speed proper for cutting the material with the most productive effect, which for the metals is sometimes as low as ten or twenty feet per minute, measured at the tool, and for the woods the speed is above ten or twenty times as great.

The principal limit of velocity in cutting machines, appears to be the greatest speed the *tool* will safely endure, without becoming so heated by the friction of separating the fibres as to lose its *temper* or proper degree of hardness.

The cohesion of iron being very considerable, a velocity materially exceeding ten to twenty feet per minute would soften and discolor the tool, whereas in general the tools for iron are left nearly or quite hard. Brass, having much less cohesion than iron, allows a greater velocity to be used; lead and tin admit of still more speed; and the fibrous cohesion of the soft woods is so small, that when the angles of the tools are favorable, there is hardly a limit to the velocity which may be used. Water, soap and water, oil, milk, and other fluids, are in many cases employed, and especially with the more fibrous metals, for the purpose of lubricating the cutting edges of the tools to keep down the temperature, the fluids reduce the friction of separating the fibres and cool both the tool and work, thereby allowing an increase of velocity; and at the same time they lessen the deterioration of the instrument, which when blunted excites far more friction, and is likewise more exposed to being softened, than when keen and in perfect working order. There are, however, various objections to the constant use of lubricating fluids with cutting tools.

The velocity of the other primary motion is generally very small, and often intermittent; and it becomes a mere creep or traverse motion, by which the pointed tool is gradually moved in the second direction of the superficies under formation.

In producing circular bodies, one of these primary motions becomes circulating or rotary, and in complex or irregular forms an additional movement, making in all three, or *sometimes* four, are compounded; and lastly, when linear or figured tools are employed, one of the motions is generally expunged.

DAMS. An erection of earth, wood or masonry, above the channel of a stream, for the confinement of the water for the purposes of navigation, or for water supply.

Fig. 62 represents a section of the Dam across the Croton river, which supplies the city of New York with water. The base of this work is composed mostly of cob, or crib-work of logs or timber, their intervals being filled in with stone, and the intervals between the piers of crib-work, with concrete. The upper portion, and the apron, or down stream face of the dam, is made of cut stone. A secondary dam is constructed below, in order that the discharges or overflow of the water may fall into back-water, and in that way check the force of the current. Dams constructed in this way, with a curved or inclined apron either of stone or wood, are called *rolling* dams. When the foundation is upon rock, it is cheaper and better to make the dam without an apron, the water falling directly upon the ledge. The slope of the upstream face of the dam in this case, is made at an inclination of 2½ or 3 horizontal to 1 vertical, in order that the tendency of water passing over it may be to press it down upon the foundation than to displace it. In timber dams, the most usual form is to place main timbers perpendicular to the face of the dam and at the inclination of the face, in frames or sections from 3 to 8 feet apart, these frames consisting of inclined timbers blocked upon each other. The foot of the timbers being bolted securely to the ledge, the face being formed by thick planks treenailed upon the outer timber, the slope is then loaded with gravel. In some cases the upper timber is inclined, and the lower timbers placed horizontal.

Dams constructed of masonry are laid full in cement, or dry, with a sheet piling of brick or stone laid in cement, on the upstream face. Their forms are various, but they should be of sufficient section to resist the pressure of the water, for calculation of which, see WALLS.

In all dams for permanent purposes, it is of the utmost importance that they should be well secured at the bottom, to prevent the water passing beneath the structure. This is usually effected by sheet piling of plank or masonry on the upper face, and to prevent any wash at the wings, the spiling is extended into the banks at the sides, or in case of rock, connected with it.

Temporary dams are often made of crib-work floated into the stream and loaded, gravel being thrown on the upper side to make them tight. By felling of trees across the stream and filling in with branches, straw, turf and earth, a temporary purpose may be served.

Of the obstructions caused by dams, the height to which the water is raised by such structures, see HYDRAULICS.

DADO. A term for the die or plane face of a pedestal. The dado employed in the interior of buildings is a continuous pedestal, with a plinth and base moulding, and a cornice or dado moulding surmounting the die.

DAMASQUINE. A term applied to ornamental work of gold or silver, incrusted on iron or steel.

DAMPER. A valve placed in a chimney, to diminish the draught when the heat is too intense.

DERRICK. A species of crane for the raising of heavy weights, &c. It differs from the crane properly so designated, in that the boom or arm is movable. It is chiefly applied in constructions, whilst the crane may be considered a fixture for workshops, foundries and warehouses. Fig. 1032 represents the common form of derrick, used for the setting of small stone, in this particular example, as the building of the Dry Dock in Brooklyn. Its construction will be easily understood from the figure. The mast is supported in its upright position by radial guys, made fast severally to posts set firmly in the ground. The weight to be raised is attached to the lowest block, which is suspended by means of another

* Holtzapfeld's Turning and Mechanical Manipulation

block to the end of the boom. The rope passes over a pulley or shear in or on the boom, and thence over another near the top of the mast, thence passing down parallel to the mast, it is attached to a barrel or drum, and can be taken up or let out by means of a geer and pinion and crank, thereby raising or lowering the weight. The boom can be raised or lowered by means of the rope at the bottom of the mast, which is passed two or three times round a small fixed cylinder, and is united to the end of the boom by a system of blocks. By the slacking of this rope, the boom may be lowered whilst the weight is suspended, which enables the workmen to take up the stone at one distance from the mast, and lay it at another more remote. The machine is swung into position by a small rope attached to the end of the boom or to the weight itself.

1031.

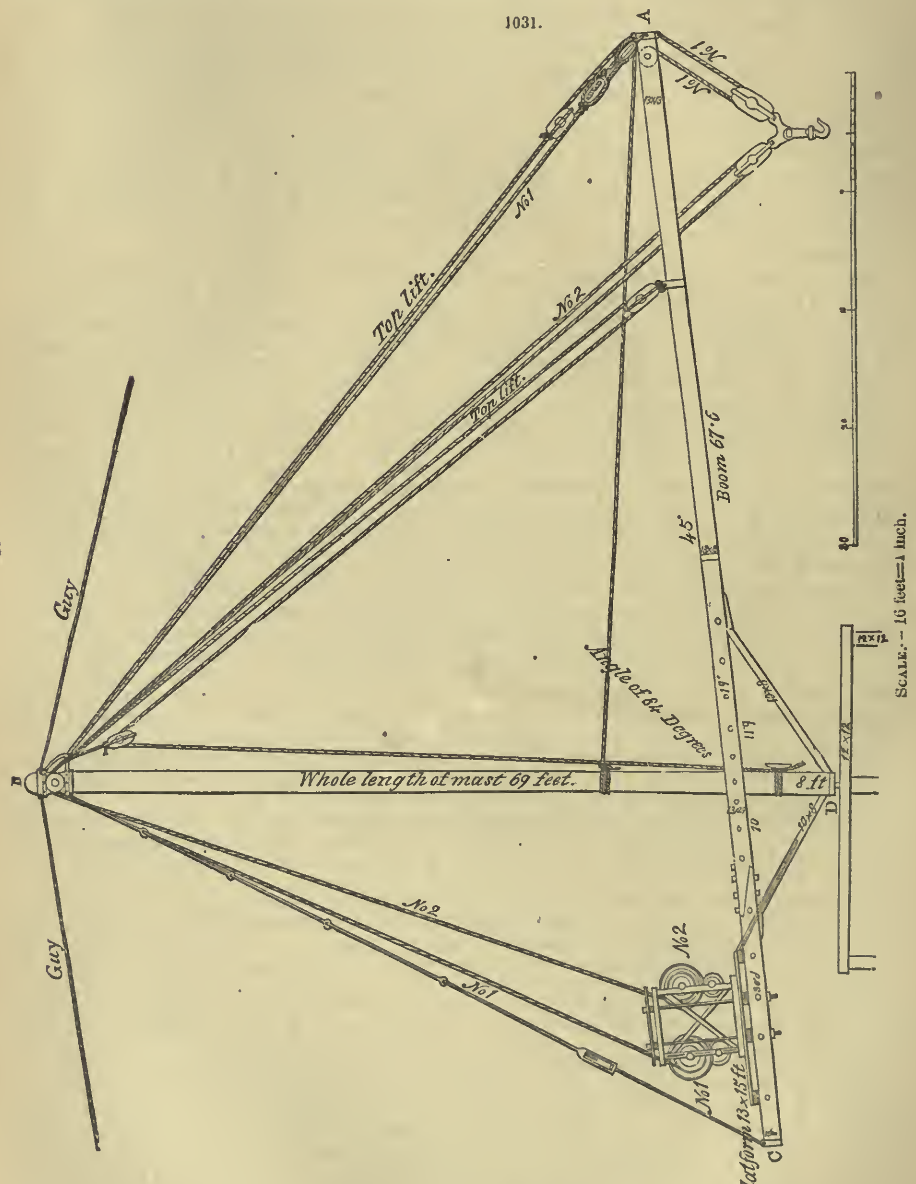
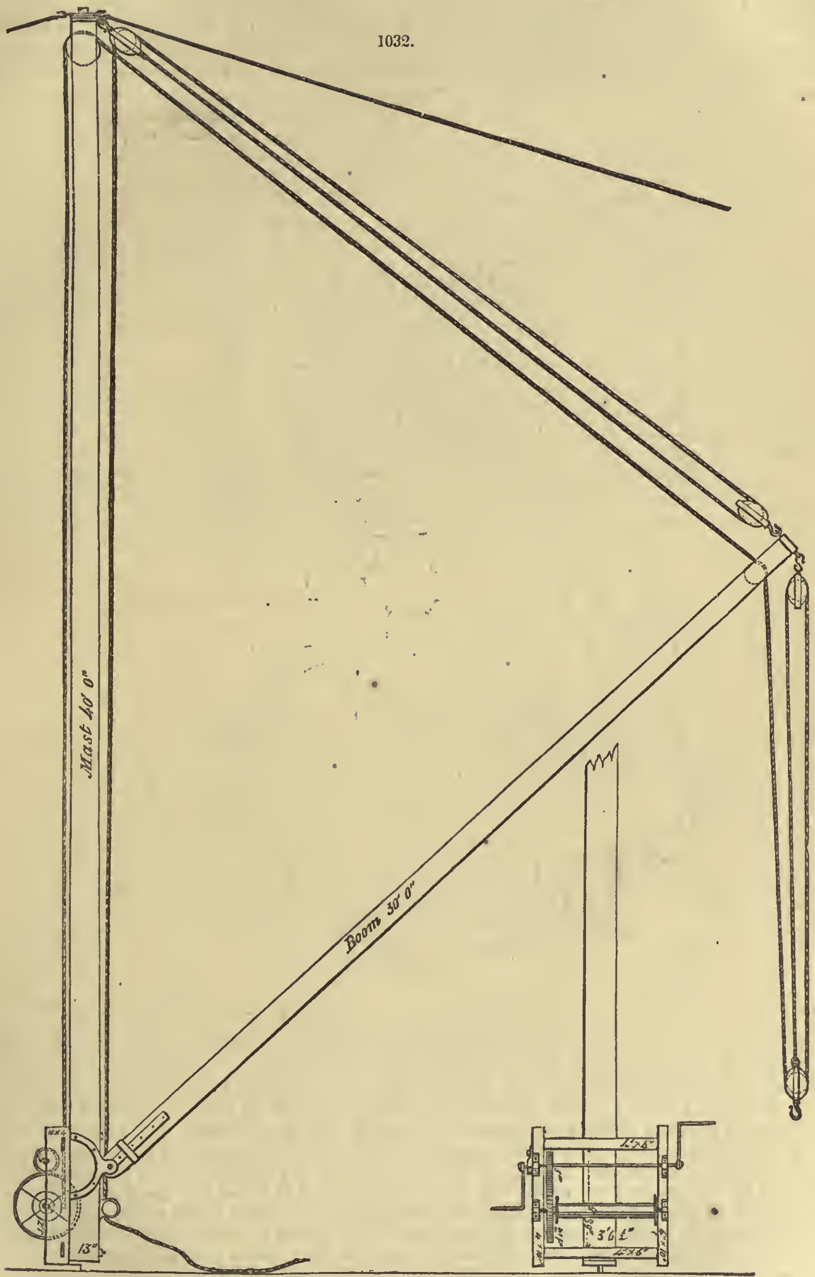


Fig. 1031, represents Savage's Derrick as improved by Mr. McAlpine, and used at the Brooklyn Dry Dock for the laying of the heaviest stone. It differs somewhat in its arrangement from the simple machine already described. It will be seen that the hook for the suspension of the weight, is supported by two blocks. By tracing the position of the rope No. 1, it will be seen that by it the right hand one of

these blocks can be raised or lowered by means of the crank, pinion, geer and barrel. No. 1 of the crab, at the opposite end of the boom; in a similar way, the left hand block is raised by rope No. 2. Thus it will be seen that by the winding up of rope No. 1 on the barrel, a motion upwards and outwards is given to the suspended weight, whereas by the winding up of No. 2, the weight is raised upwards and

1032.



Scale.—6 feet=1 inch.

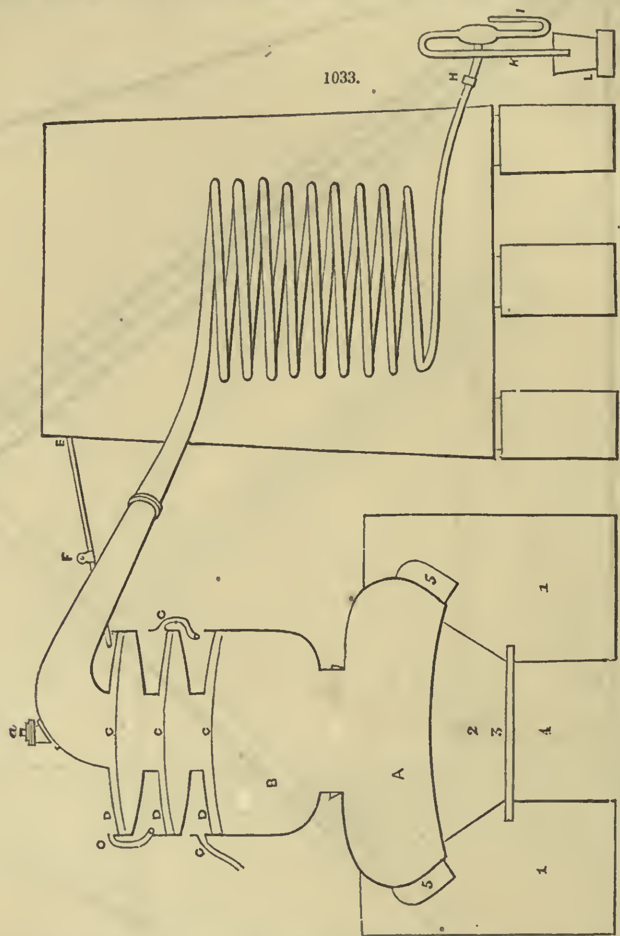
inwards. Again, if rope No. 1 alone be slackened, the weight is lowered and tends inwards, and again if No. 2 be slackened, the weight is lowered outwardly; by these means the stone may be deposited at any spot within reach of the boom.

DISC ENGINE. See Engine.

DISTILLATION. The evaporation and subsequent condensation of liquids and even solids. The vessel used for generating the vapor if of large size is called a *still.* Distillation as carried on by the chemist is usually by means of *retorts*, and the vessel that receives the distilled matter is called a *receiver*; this is perhaps the most simple method of distilling. The distillation of coal in the manufacture of illuminating gas is conducted in cast-iron retorts, and is an example of this form of distillation.

There are two distinct operations in the production of ardent spirits. The one is the conversion of certain vegetable principles into alcohol, the other the separation of the alcohol from other substances with which it is necessarily blended in its production. The vegetable principle which is essential to the formation of alcohol is sugar, and this is sometimes used directly, as when molasses and like products are

1033.



subjected to immediate fermentation, or it is indirectly obtained by subjecting amylaceous grains to certain processes by which the starch they contain is first converted into sugar, and the sugar afterwards alcoholized. For this latter purpose, the various grains are subjected to the operation of bruising or *mashing*, and infused under constant agitation in a proper quantity of water in the mash tun. In this way the *wash* is obtained which is run into the fermenting vats, where mixed with a small quantity of yeast, it is subjected to the process of fermentation which requires from 6 to 12 days, the term varying with the mass of liquid and the temperature of the atmosphere. As the fermentation progresses, the wash attenuates; as this attenuation reaches the maximum, the wash is drawn into the still and subjected to heat, the spirit or more volatile matter passing over first, is condensed in the worm, and yields spirit. In general, the wash is first subjected to distillation, from which a weak spirit is obtained, then this spirit is re-distilled from which proof spirits are obtained, the stronger spirits being the most volatile, being the first to pass over.

Of stills there are almost an endless variety, differing not in essential principles but in detail. We instance one of the earliest improved stills, that invented by Corty, and afterwards much simplified by Messrs. Shears & Sons.

Fig. 1033 is a representation of this still: A being the body of the still into which the wash is put; B is the still head; C C C are three plates of copper fitted into the upper part of the boxes D D D, which are kept at a regulated temperature by water being conducted over their outer surface, by means

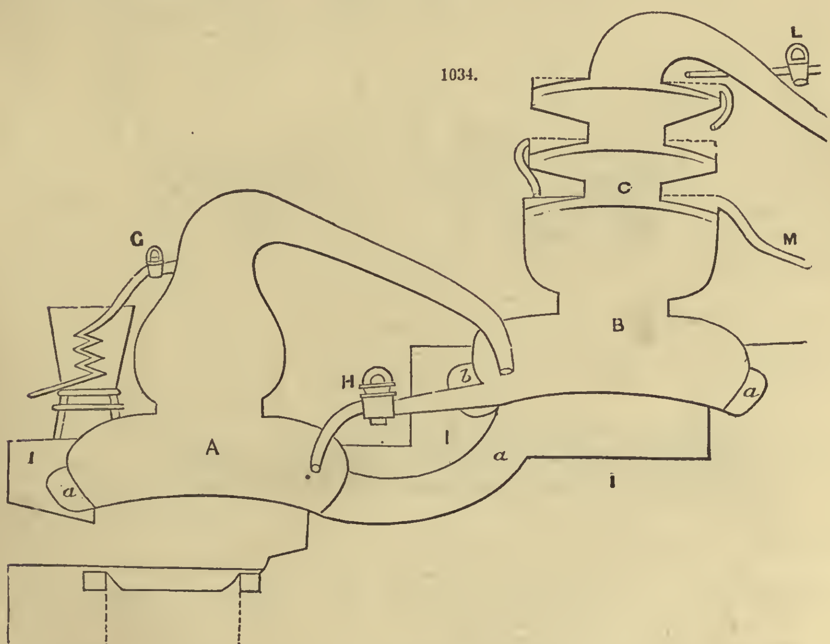
of the pipe E and the distributing pipes G G G. The spirit vapor then rising from the body of the still meets a check at the lowest plate C, by reason of the coolness occasioned by the water; this condenses the grosser part of the vapor and throws it back, whilst the lighter proceeds on to the second plate C, where a further coolness condenses another portion of the vapor, leaving a much purer spirit to encounter the increased coolness at the third plate C. Here the last separation takes place; the aqueous and oleaginous particles being unable to sustain the temperature maintained, fall back condensed, and only a very strong spirit passes over in the gooseneck. By means of the cock F, in the pipe E, the supply of water to the boxes D can be very exactly regulated; and, as a natural consequence, the temperature can be very accurately adjusted. If the temperature of the upper box be kept at 174°, for example, the alcoholic vapor which passes over will be comprised of 90 per cent. of pure alcohol, or 65 over proof; but with a temperature of 194° Fahr. the vapor will contain only 66 per cent. pure alcohol, or 30 per cent. over proof. *a* is a screw-cap, through which a jet of steam or water may be sent to clear away the deposite, which otherwise will more or less accumulate on the upper surfaces of the plates C. At the lower end of the worm-pipe is affixed, by means of the brass swivel-joint screw H, a gas apparatus. The peculiar form of the pipe I into which the spirit runs from the worm, causes it to be filled shortly after the still commences working; whilst the other branch pipe K rises to some height, then returns, and is immersed in the small box L to the extent of about two inches in water. The gas from the still escapes by this pipe through the water, as the pressure can be but trifling.

It is held, that by means of this gas apparatus the distillation proceeds in a partial vacuum, and that thereby there is a great economy in fuel. As the spirit enters the worm at so much lower a temperature than in the old stills, that quantity of water is not required to cool the spirit vapor as would be otherwise.

A still of 400 gallons is said to work off four to five charges in the day of twelve hours; yielding a spirit on an average of 35 per cent. over proof: which, for rum, is considered the most advantageous strength to run it at.

Fig. 1034 is another arrangement of the same kind of still; being the addition of the common still A to the patent still B. In this case the contents of B are drawn down from time to time into A, and that of A run off as dunder; the spirit from A being conducted into B. One fire heats both stills; and it is stated that by the general adaptation and arrangement, a very large quantity of fine spirit is produced by the consumption of a very inconsiderable amount of fuel.

1034.



DIVING-BELL. A box, shaped somewhat like a bell, and usually constructed of plate iron, intended for the purpose of enabling a person to descend beneath the surface of the water. It is open below, and is lowered into the water, the air beneath being condensed in proportion to the depth to which it is sunk beneath the surface. To give sufficient air-space in the bell, and to supply fresh air for the purpose of breathing to the parties within it, air is forced in from above through a flexible tube by means of a condensing pump. This machine is extremely valuable in setting foundations beneath the water, and in making examinations of sunken wrecks.

DOCKING SHIPS, *Apparatus for*. The Marine railway. The *slip*, Figs. 1039 to 1042, consists of three timber ways laid down on piles or on the firm beach, and running into deep water. These ways carry a rail, on which work the trucks or rollers of the carriage or frame D D. This carriage or frame

consists of three strong longitudinal trucks, secured together by six, seven, or more movable cross-pieces, the carriage being hauled upon the ways by means of a wheel and pinion, capstan, or other purchase. On the keel-beam D of the carriage, blocks are laid to such a height that the keel of the vessel may clear the ends of the cross-pieces, and each block carries four rollers. On the cross-pieces, on each side, are laid sliding or chock-blocks F F, which are made to suit the rising of the ship's bottom, and are worked backwards and forwards on the cross-pieces by tackle. They are also secured on the cross-pieces by a rack and pawl. On the aftermost cross-pieces are also two shores I I, which turn upon a joint, and are prevented from falling outwards, when the vessel is floating on, by means of a small chain.

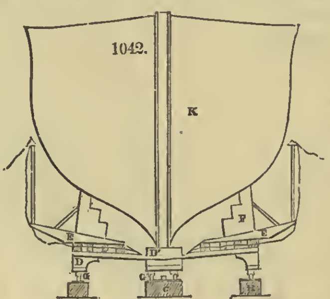
A vessel having floated on to the slip, the sliding-blocks are adjusted by the tackle under her keel, the tackle being taken on board the ship, and hauled tight. By this means the sliding-blocks are brought into the proper place, and the pawls fall into the racks on the cross-pieces, and wedge the vessel firmly in. The iron guides at her forefoot and at her stern are also hauled up, so that she is well secured to the carriage. Of course, the carriage being inclined, the vessel takes first the foremost blocks, but the others are gradually adjusted, and as the carriage is hauled up the slip, the vessel takes the remaining slide-blocks in succession. When duly prepared, the vessel and carriage are hauled up the slip at the rate of from $2\frac{1}{2}$ to 5 feet per minute. The power employed is in about the proportion of six men to every hundred tons.

When hauled up, the vessel is shored from the ground, and the keel-beam being relieved from the weight can be run back so as to be used again. It should be observed, that during the hauling up, the carriage is prevented from falling back by means of three or more pawls at different parts of the framing, working on the rack on the midway.

The launching of a vessel from the slip takes place very easily, by putting the cross-pieces and chock-blocks under her and the keel-beam.

This slip admits of more than one vessel being on the slip at the same time, as the carriage or cradle is movable, and the vessel, when ashore, can be shored up in the usual way.

1042.



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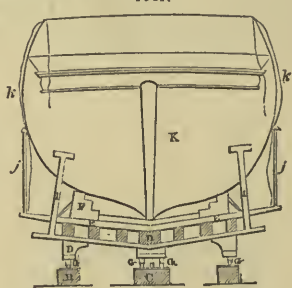

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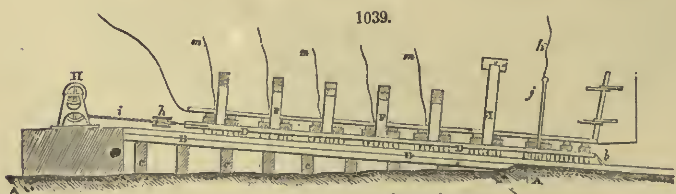

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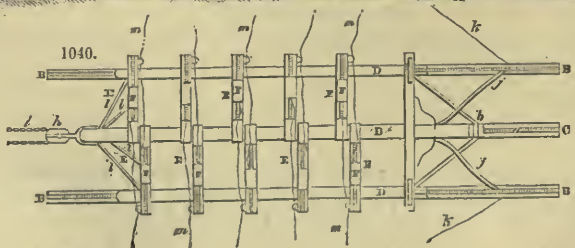


The American Marine Railway, or the Railway Dock, as it is styled in the patent. The plan of construction is thus described by Mr. J. L. Sullivan, C. E. :—

"The bottom is to be levelled to the proper slope. The foundation piles are to be driven in four lines; the two inner rows near to each other, in order to support the keel; the two outer rows to come under the shores. The piles to be cut off under water must be cut off in the exact inclination of the plane, and level

with each other transversely. The necessity of previously marking each pile separately, on every side, in accordance with the intended inclination of the ways, led to the invention of instruments requisite to the occasion.

"*An aerial inclined plane* parallel to that intended to be established under water is obtained by first fixing a true level across the head of the railway, and denoting each station by a target, the staff of which is so much above the line of plane as will bring the lower end of the aerial plane above water; targets, having each a staff of the same length, being next applied, and nailed to the outer, and some few to the intermediate piles, will exactly indicate the aerial inclined plane, while the point of the staff attached to the pile will indicate a point on one side thereof in the intended plane of the foundation.

"The *level and bevel* is an instrument by which to ascertain every other point on the sides of the pile which will be in the intended inclined plane. Fig. 1043.

"The *diving-bell* may now be supposed to be brought over the pile, and as much of this as it will take in cut off, together with the target staff, still leaving the lower end. This cutting is repeated till the workmen arrive in the bell to the bottom of the staff, which remains a little below the last rough cutting. The level and bevel is then set on: this consists of a base-board, with a post arising from its centre to support a plumb-line playing in a cant piece having a centre notch, to determine whether the base is level transversely; and as this base is at the same angle with its post that the intended plane is to a perpendicular line, and the base being equally thick, its under side also indicates a parallel plane, so that, being secured in its place, the distance is measured by compasses from the ascertained point to the base-board, and thence to every point in the circumference of the pile that is also in the intended plane, thus marking it with accuracy for cutting. This operation being the same for each pile, it results that every one must be truly in the intended inclined plane, ready to receive the frames of the railway, which are floated over, and sunk down to their places; or a plank is first secured upon the head of the piles, upon which the frames are successively slid down.

"The *iron rails* will, in point of size, depend upon the weight they are to bear. They must of course spread a sufficient base to prevent being indented into the wood by a heavy load. The two middle rails, and the rack piece for the pawls, are generally cast in one; but if the rails are to be of rolled iron, the rack will be separate. The pawls prevent the ship from accidentally running back.

"The pressure of the load will, in merchant ships, be greater forward and aft than at midships, because they generally become a little hogged; provision must therefore be made for this contingency, and it will be safe to suppose cases in which the largest class of ships to be received will bear all their weight on the first 10 feet forward and the last 10 feet aft.

"The weight of a ship is often erroneously stated to be as many tons as she measures tons. The fact is, that when laden she displaces a quantity of water that would precisely weigh her whole weight, cargo included; and, as she generally carries as many tons as her measurement, she cannot, when light, weigh as many tons as she measures; she weighs only as much as the water she then displaces, and that will be in accordance with the weight of her materials, oak, pine, or cedar. Wherefore, for explanation, I shall suppose the positive weight of ships to be one half of their nominal tonnage.

"A ship of war will be received upon a railway carriage with the precautions to be subsequently explained, and its weight distributed equally over it and the foundation. The tendency of all ships being to acquire some curvature of keel, it will generally be injudicious to straighten them on the dock, as they will resume their lines on being again put afloat, opening thereby the upper seams or butts. To keep the ship, when taken out of the water, in precisely the same shape she has in it, the curve of the keel must be ascertained, and the keel-blocks be made to conform thereto.

"To *measure the curvature of the keel* we have devised an instrument, consisting simply of a bar, suspended at each end by a graduated chain. This bar, being long enough to reach across the ship, is passed under and across her centre at every five or ten feet, when the graduations on the chains will show the difference of depth at every point of contact from stem to stern. For merchantmen this precaution will not generally be necessary.

"A ship of 500 tons measurement will exert a pressure of 250 tons, and we have supposed the whole of this may have to be borne by the two extremities of the carriage, or by 10 feet at each end. The axles, therefore, are at the extremities, but nearest to each other. But as steamboats will bear heaviest in the middle, the axles must be near in the centre also, for their support.

"The axles will be two feet apart in the first 10 feet. Five axles will have to bear 125 tons, or 25 tons each; the bearings and wheels 12½ tons. The axles of the New York Dock are 3 inches diameter, and the square of the section is 7.071 inches. The bearings are close to the wheels in which the axles are fixed.

"*The strength of the rail* is deduced from experiments, from which it resulted that a rail of 1 square inch would be ample; but a rail of 1 inch is too narrow to be favorable to the duration of the wheels.

"The central axles of the New York Dock weigh but about 1 ton, and would together suspend 9,300 tons.

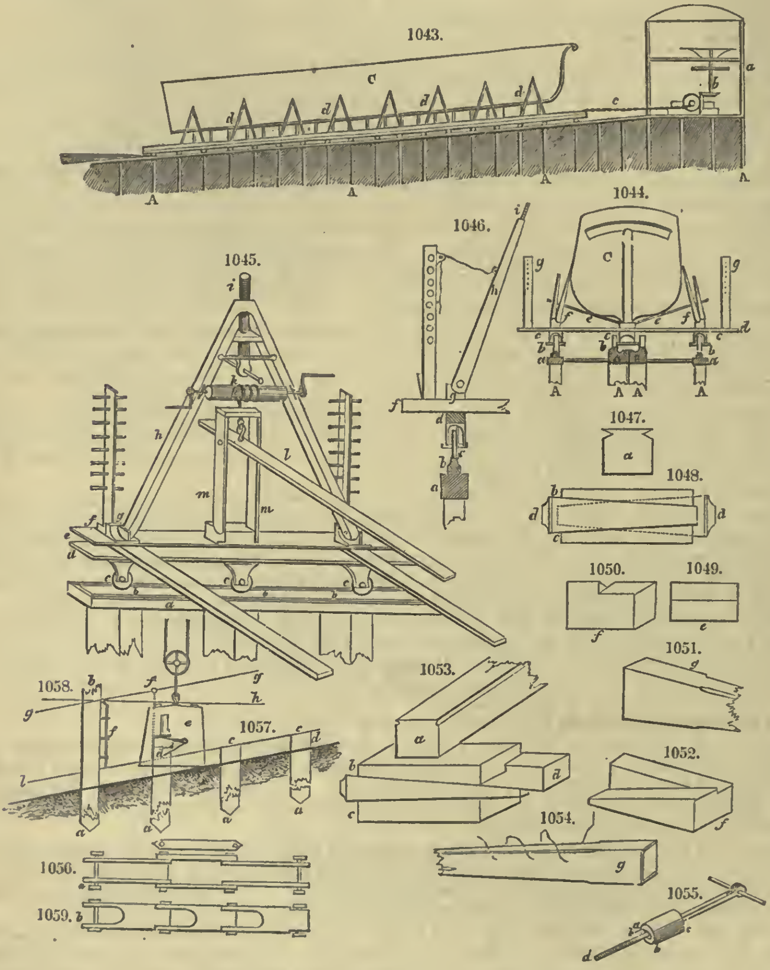
"The friction of the axles should be relieved by the intervention of brass bearings, as usual in machinery.

"*The side axles* will sometimes have a proportionate share of the ship's weight to sustain; though she will ordinarily be prevented from inclining on one side or the other by the *adjusting-screw* placed at the angles of the shear-shores; yet it is necessary to guard against the force of high winds, and the weight which a hogged ship may sometimes throw on the centre shores, before she is eased down at midships by the screws, if intended to be straightened. (Fig. 1045 *i.*)

"*The carriage* is combined in a very strong manner, though it appears to be rather a light structure for the purpose. In its construction the implement called the dowelling-bit is of great and essential use. (See Fig. 1048.)

"The *dowell* is a cylinder of some hard wood, generally lignum-vitæ, which is one half inserted into one, the other half into the other timber, where a joint is to be made of their surfaces, which the dowell prevents from moving or sliding on each other. The gouge and the screw, perceived on reference to Fig. 1055, are also improvements. An auger hole, a little smaller than the screw of the bit, being first bored, the thread will cause the bit to advance as fast as the chisel and gouge can conveniently cut, and thus the whole labor is confined to turning it.

"The instrument now makes it easy to dowell the frames of a ship, the knees to the timbers, the waterways to the beams, the thick stuff of the wales to each other, and generally to bind the ship by a solid connection of wood.



"By means of irons and the dowell, the *cross-ties* are secured to the sills in such a manner as to make it impossible that the carriage should spread; and by thus tying the sides to the centre, the cross-timbers convert the oblique force of the shores into vertical pressure; and care is taken in every instance *that a wheel shall stand directly under the base of every shore.*

"The shear-shores (Fig. 1045) have a form which gives them great stability in their places, and answers other purposes to be mentioned; they are bases in *hollow coin blocks*, either of wood or iron, divided across the middle of the hollow by a partition, which serves to hinge the two legs of contiguous shears. There is thus a continuity of solid material from the side of the ship to the foundation, from the moment she ceases to float till she is high and dry.

"The *shear-shore screws* will sometimes have the important office, when ships are old and tender, of taking a good share of the weight of the ship's side, and distributing it along the carriage side, taking it off from the floor timber-heads, futtocks, and beam-ends, where ships are most liable to be weak.

"The *bilge levers* (Fig. 1045) are levers of the second class. One end is lodged fixedly on the centre sill of the carriage, while the other end is hove up between the legs of the shear-shores by a windlass placed within them. The moving end is guided in a slot of the prop, and sustained, when up to contact with the bilge, by means of an iron pin passing through the cheeks of the prop.

"The *cradle* thus formed by the bilge levers it is evident *will fit every successive vessel equally well*, and may thus be removed singly, and replaced as the work progresses; and as they require to be hauled up with considerable force, nothing can be desired more convenient than these shears.

"The *common keel-blocks* are of course placed between the cross-ties, and are of such height as to allow ample room for the shipwright to work under the flat of the bottom, standing between and on the cross-timbers. But the bottoms of the keel will sometimes have to be repaired. To accomplish this end, the instrument called the lifting-plane has been devised, (Fig. 1046.) In the operation of this machine, two wedges are forced on by percussion; blows from opposite sides being simultaneously given, with the combined strength of a considerable number of men, when the resistance renders it requisite.

"The *lifting-planes* are composed of six pieces of timber, and for the navy may be made of cast-iron, or of wood faced with iron. To make them, let us suppose a block 4 feet long, and 16 inches square, halved horizontally, and each face of the cut marked lengthwise, and then shaped into two similar planes inclined in opposite directions. The two planes are then divided from each other by a bar of iron, let in edgewise till its edge is flush with the upper ends of the two planes, in order to guide the wedges. Now let the upper half be placed in its original relation to the under one, (over it,) and there will be space for two wedges, pointing in opposite directions parallel to each other, separated by the bar of iron before mentioned. The planes being eight, all at the same angle of inclination, the upper block, with whatever may be upon it, will be lifted perpendicularly by driving the wedges. These require heavy blows, and for this purpose battering-rams, swung each between two files of men, are necessary. (Fig. 1046.)

"In practice, one of these machines placed near a keel-block is easily made to take the pressure from it by the least degree of lifting, and thus several machines may be applied, so as even to take away all the common blocks, and they themselves may be readily withdrawn and shifted in position, so as to allow the bottom of the keel to be got at for coppering, shoeing, or renewing; and when done, the common blocks are to be replaced. To do this, when a ship is hove down, her keel must be hove completely out of water.

"The chain and compound windlass by which the ship is hauled out is an expensive and essential part of the machine.

"The *power to draw up a ship* of 500 tons, weighing, as before assumed, one half the same number of tons, is now to be considered. From the experiments made in different places, the weight which the chain must bear is 40,320 lbs., or 18 tons.

"The chain of a marine railway must be, however, exposed to accidental stress beyond this calculation. It has to ply around a ratchet-wheel, and animal force is often irregular. A steam-engine would therefore be the best.

"The shape of the chain, in order to give it a degree of strength proportionate to the material, is of importance, as it has to bear the stress of turning around the ratchet-wheel of the windlass.

"The windlass is also so geered as to adapt it to the power of a few horses. When they travel in a walk the ship moves up the plane about 3 feet a minute, and she is completely up in less than two hours. Four horses are a sufficient force for a ship of 500 tons. The horses work in the second story of a small building; they are attached to bars 14 feet in length, proceeding from an upright shaft, on the lower part of which is a bevel-wheel communicating with the rest of the geer.

"The end of the chain is strongly fastened to the centre of the carriage, with branches passing obliquely to the sides, so that the whole must move equally, and at once.

"The *reversal of the draught* at will is an essential provision, in order to draw the carriage out to the extremity of the ways, to which its own gravity would not certainly carry it, because to be able to give the carriage such a position as to afford just water enough for the ship to ground on the upper blocks is indispensable. To be able to refloat the ship, should she happen by bad management to ground otherwise than on the centre of the carriage, may, if on a falling tide, be of great consequence; we must therefore have the readiest means of drawing the carriage down the ways. With this view, the chain, after passing the *haul-up wheel*, is led to another ratchet with reversed teeth, and thence down along in a trunk by the centre timber of the ways till near their extremity; there it turns around a large and strong shiver, and fastens about 20 feet from the end of the carriage, which the chain follows, when drawn up, it being supported on rollers. The reversed movement, of course, draws the carriage down till it touches the stop-block at the outer end of the railway. The chain is thus disposed of without manual labor. The connection of the second ratchet with the first is by intervening geer, so that they move alike.

"The ship in descending requires a controlling power, that she may not acquire momentum, and injure the carriage by velocity. The friction for this purpose is produced by means of an iron wheel on the upright shaft, placed just below the floor. An iron band is made to clasp this wheel by the aid of a powerful lever. This is found to be quite sufficient, and very convenient.

"The manner of receiving a ship is this:—she is brought between the wharfs of the dock, head on; the carriage is drawn down under her, and perhaps up a little, till her forefoot grounds on the forward block, and as ships generally draw more water aft than forward, she is nearly aground aft also; the head-shores are applied, she is then moored up a few feet, until she is ascertained to touch aft also; the shores are now all applied and secured, and the bilge levers are hove up to their bearing; she is now ready to rise into the light and air.

"The wheels or sheaves running on the rails are made small, because it is an object to keep the carriage low, that we may not have to extend the ways further than is necessary to get the desired depth of water on the carriage.

"This structure, it is to be observed, is only accessible for repairs by the diving-bell. In all places exposed to the worms the timber must be coppered, unless the white gum tree is found to be unassailable, as some have represented."

At New York there is also a company called the New-York Screw-Dock Company, to whom belong

the screw-dock, and the hydrostatic screw-dock, which is an improved form of the invention, and with hydrostatic power brought to bear as the lifting force.

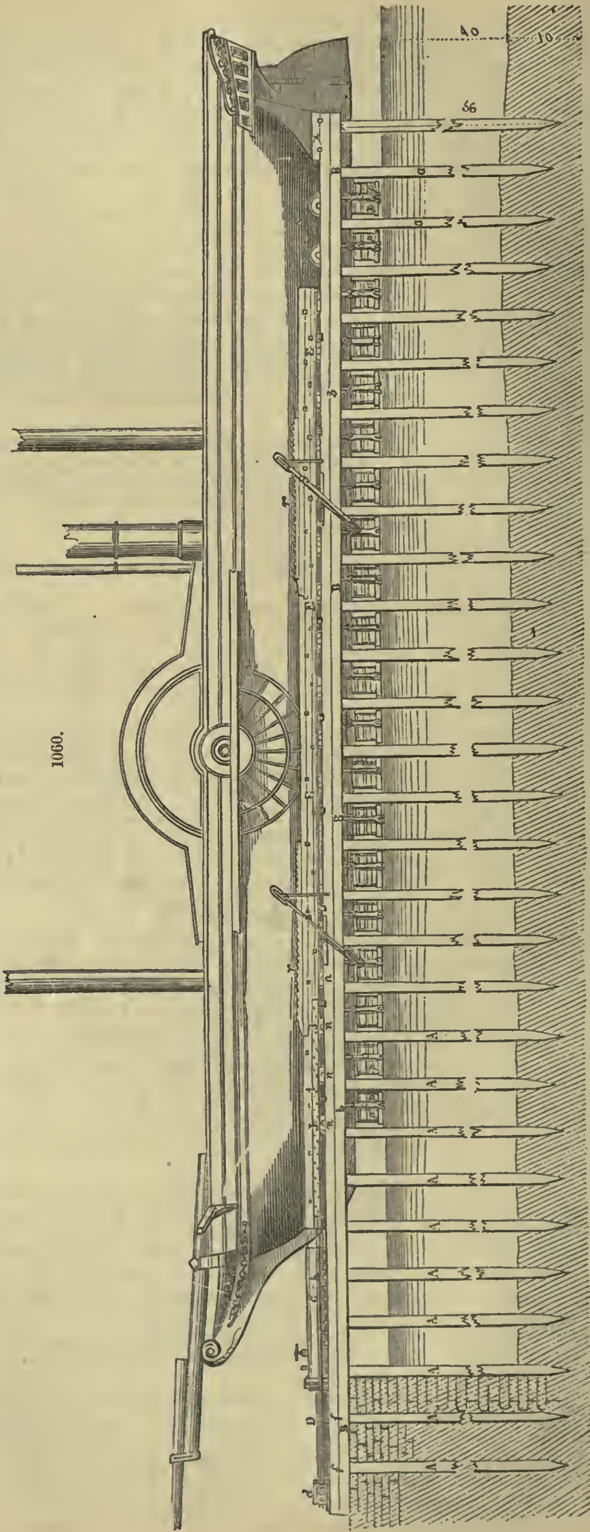
The screw-dock in general principle and form is the same as the hydraulic screw-dock. The vessel in the screw-dock is floated on to a timber platform, which platform is suspended from strong mainway pieces of beams on each side, laid on the quay walls, by eight suspending screws four and a half inches in diameter. The platform is capable of being sunk about ten feet below the surface of the water, to receive the ship.

This platform has several shores on its surface, which were brought to bear equally on the vessel's bottom, to prevent her from canting over on being raised out of the water. About thirty men were employed in working this apparatus, who, by the combined power of the lever, wheel and pinion, and screw, succeeded, in the course of half an hour, in raising the platform, laden with a vessel of 200 tons burden, to the surface of the water, where she remained high and dry, suspended between the wooden frames.

In a dock at Baltimore, of this kind, the platform is suspended by forty screws of about five inches in diameter.

The Hydrostatic Screw-Dock is a slip abutting on the shore, with a suspended keel, allowing the vessel to be raised up vertically, instead of being drawn up on an incline, as in the slip and the marine railway. It consists of two outer and parallel ranges of piling, each bearing a way at the top, from which are suspended chains, to which are slung transverse bearers or swing beams, over which the vessel to be docked floats; and having arrived over this moveable platform or grating, the chains are raised by means of a hydrostatic press, and the vessel brought to the level of the permanent way. The means by which the apparatus is worked are ingenious, and constitute the chief merit of the application.

The dimensions of the dock are about 165 feet long internally, and 35 feet wide. The distance from the outside of one mainway to the outside of the other is 51 feet. The mainways abut on the land, and run about 38 feet beyond the head of the dock on to the land, resting on a solid quay of masonry, to which they are bolted down, and which supports the machinery.



1060.

We shall first describe the construction of the two parallel mainways. These ways (B B, Figs. 1060 to 1069) are placed 35 feet apart, and each consists of a row of double piles A A, with every pair placed obliquely; thus, A. The piles are of the best Georgia pine, 56 feet long and 20 inches square, with iron shoes, and with their heads mortised into the mainway pieces, and bolted together with 1¼-inch bolts. The divergence of the double piles from the perpendicular is about 3 feet at the lowest extremity. The piles in the longitudinal direction of the ways are placed 4 feet 8 inches apart. The depth of water at the site of the dock is 40 feet, needing no excavation; and the piles are driven into the foundation soil about 8½ feet. Some of the piles are further apart than others, depending upon circumstances and contingencies, but the general distance is about 4 feet 8 inches. The total number of pairs of piles in each way is about 29, making a total of 116 piles. (Fig. 1060.)

The mainways B B are, as already mentioned, scarfed or mortised on to the top of the double piles, and secured by iron 1¼-inch bolts, Figs. 1060, and 1061. Each mainway is 182 feet in length, and is formed of Georgia pine logs, placed five together . . A . . , and bolted together by the same bolts which secure the heads of the piles. These ways are about 4 feet 10 inches broad and 2 feet 10 inches thick. Through the mainways, passages are left for the suspending chains. At the end of the mainways are chocks Z to prevent vessels from slipping off.

On each mainway, again, are mainside straps E E, Fig. 1060, being double, and each composed of three pieces of Georgia pine, the centre about a foot thick, and the others about 8 inches, making a total height of 2 feet 4 inches, and a breadth of about a foot. The mainside straps stand about 10 inches apart, and are secured together by strong bolts and square trenails of locust-wood z* The straps are 124 feet in length. The side straps are secured to the cylinder C, by side straps of wrought-iron, 32 feet in length and a foot broad, bolted in, and fastened to the side rods h of the cylinder by a large gib i, Fig. 1062. On each mainside strap are two ratchet-plates and pawls, hereafter to be described.

At every 6 feet 4 inches in the mainside straps, a wrought-iron cross-bar or distance piece l is fixed in, which is an eye or box u, to receive the head of the suspending chain k. This head consists of a screw m, secured by a nut, which regulates the height of each swinging beam so as to fit the keel of the vessel. From the screw m a chain k descends, passing between the mainside straps, mainways, and the spaces between the piles, and terminating in a wrought-iron linkhead and cross-bar o, sustaining the transverse bearers or swinging beams p. The chains are each about 24 feet long.

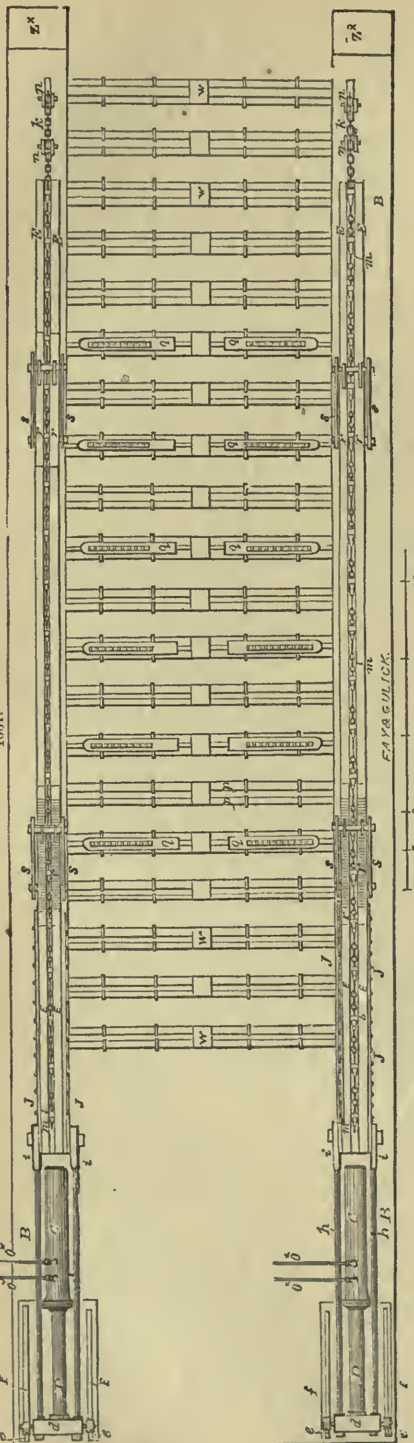
Between the two mainways B, Fig. 1061, hangs the platform of swinging beams, suspended by the chains k, which run over the sheaves n. The mainways are 35 feet apart, and the swinging beams p 44 feet long, consisting each of a double beam about 7 inches apart. The beam is of a flat triangular form, made up of large logs, fastened together by six iron straps. The pairs of swinging beams are twenty in number, and each single beam is of oak, about 15 inches broad, 3 feet 3 inches deep in the centre, and 18 inches at the ends. Each pair of swinging beams is suspended by a chain k at each end. On the centre of the swinging beam is a keel-block w, 3 feet long, 2 feet broad, and 10 inches deep, to receive the keel of the vessel. In it are boltheads also to receive blocks-tackle y, for managing the chock-blocks t. On every second swinging beam is a traverse frame q, raised on six short bearers. On this traverse frame is a ratchet-plate x, into which a pawl falls from the chock-blocks. On the ratchet-plate rests the chock-block t, 5 feet 3 inches high, 4 feet 10 inches broad, and 18 inches thick. These chock-blocks support the sides of the vessel, and are moved backwards and forwards on the swinging beam by blocks and tackle $y z$. This tackle it will be seen works both ways, and is also affixed to the pawl x.

On the quay or landside is the engine-house and pump-room, in which is the machinery of a 6-horse power steam-engine for working the hydrostatic press. In it is a tubular boiler A *, much like a locomotive boiler, 15 feet long, 3 feet broad, and 6 feet 3 inches high, with steam-pipe B * communicating with the horizontal cylinder C * and valve-box B *, which lie parallel to the boiler. This piston carries a connecting rod E *, which sets in motion the mainshaft F * at right angles, and in the direction of the mainways, by which four cranks G* G* are worked, each of which has a pair of pumps attached. Each pair of pumps has a separate cistern in the tank N *, which, instead of water, is filled with a fluid composed of equal parts of water and alcohol, to prevent freezing in the winter months. These are the pumps which produce the pressure within the hydrostatic cylinders C C. The diameter of the smaller pumps is 1 inch, and of the larger pumps 2 inches, and each set of pumps has its respective stop-valves for letting on and off to the hydrostatic cylinders C C, so that one or more may be worked at pleasure.

From the main-shaft power is also obtained for fleeting back the ram, by means of a pinion H * set in geer on the wheel J * by a clutch I *. The wheel J * is on a parallel shaft k *, carrying a pinion K *, from which a bevel-wheel M * takes the motion at right angles to another shaft M *, on which are the two pinions L L, Fig. 1062, which turn the bevel-wheels I of the parallel screws $j j$ of the hydrostatic ram, so that the power is brought to the back of the hydrostatic cylinders.

A hydrostatic cylinder C, Figs. 1060 and 1061, is attached to each mainway, secured, as already mentioned, by its side rods h through a strong gib i to the mainside rods E. The apparatus consists of two strong wrought-iron parallel side rods $h h$, 44 feet long and 6 inches diameter, united by a cross-head d, 4 feet 8 inches long and 2 feet broad, at the upper end. Within this framing is the cylinder C and ram D. The cylinder, including the glands, is 18 feet long, 18 inches internal diameter, and 2 feet 3 inches external diameter. On the top of each cylinder, Fig. 1061, are pipes o * communicating with the pump-room. The ram or plunger is 1 foot 2 inches diameter, and made sufficiently long to admit of a direct motion forward of 15 feet. The outer end is fitted with a collar x * into the crosshead d. The crosshead d, Fig. 1061, travels backwards and forwards by means of rollers e on a cast-iron way f, laid on the mainways B. At the dock end the mainside rod h is crossed by the fleeting shaft M * from the engine-room, already mentioned, and the pinions L, on which work the wheels I of screws j, secured by a box K to each of the side rods h, Fig. 1062. At the extremity the side rod h carries a roller M and handle N.

We shall now proceed to describe the process of taking a vessel into the dock. The hydrostatic



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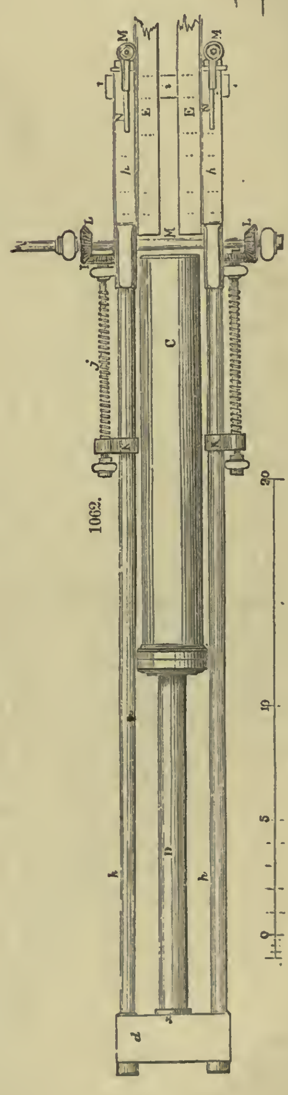

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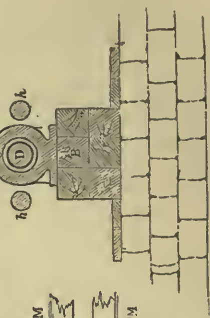

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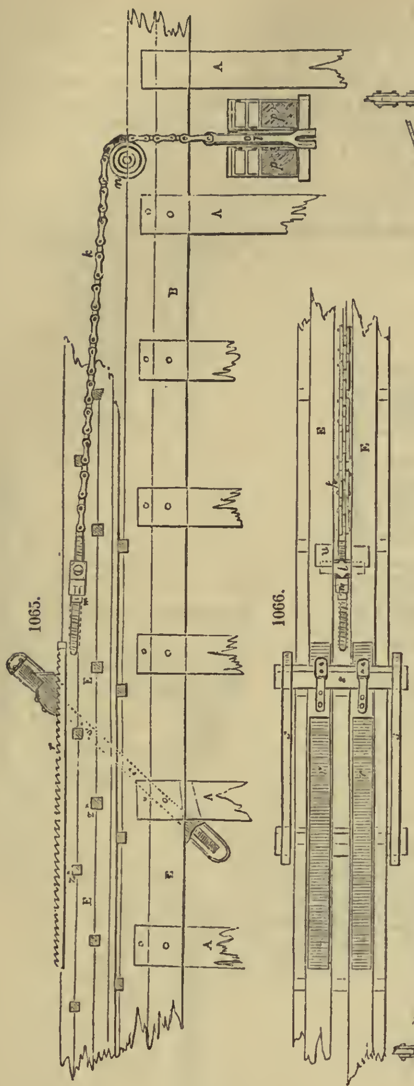

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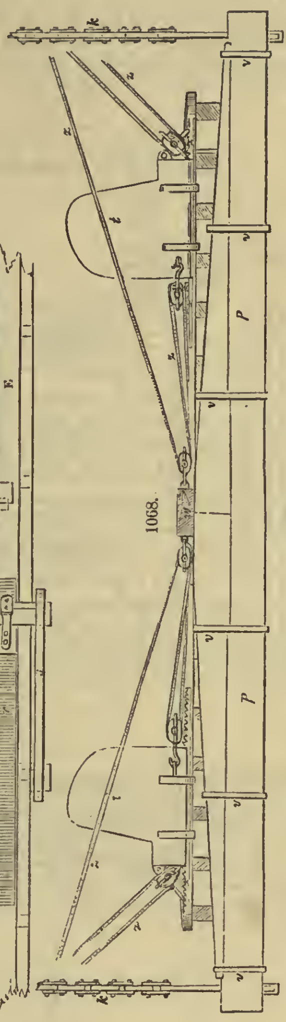

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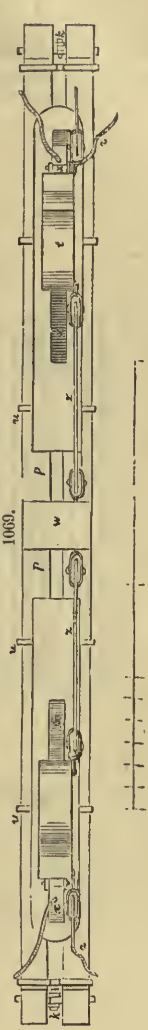

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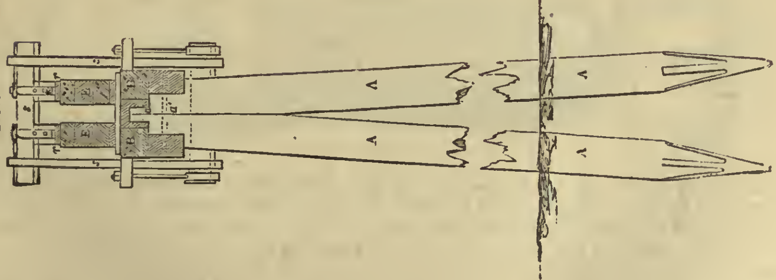
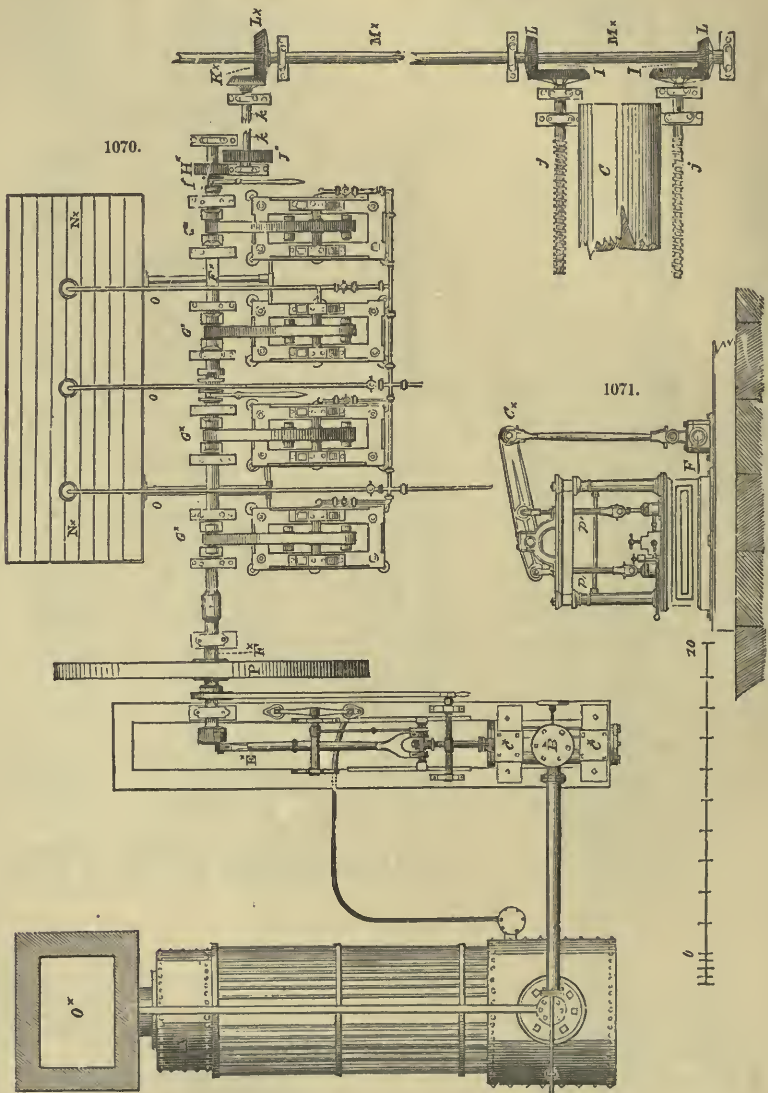


engines are charged with water, and the rams D forced out to the full extent of their stroke. By this means the mainstraps E are drawn towards the head of the dock, and the cradle of swinging beams lifted up, so as to allow of the adjustment of the keel-blocks *w w* and chock-blocks *t*, and of the swinging beams, by means of the adjusting-screws *m*, to the suspending chains. The cylinders are then discharged, the rams fleeted back, the pawls loosed, and the cradle of swinging beams sunk again by its own weight, the mainstraps being checked from running over the mainways by the chocks Z*. It will be observed that the cradle may be stopped at any required depth by closing the escape-valves, and by lowering the pawls-bars *s* on the ratchet-frames *r*.

1070.



1071.

The vessel to be repaired is then floated into the dock, brought over the keel-blocks, and the hydrostatic engines and pumps set to work until sufficient pressure is created to raise the swing beams up to the keel. The motion is then stopped, and the traverse frames *q* and chock-blocks *t* hauled in by the tackle towards the centre of the cradle, so as to take a uniform bearing under the body of the vessel. When they have done so, the pawls *x* are let fall on the rack so as to fix them in their places, Fig. 1066. The vessel is now shored up and the engines again started, when by the hydrostatic pressure the rams are forced in a few minutes out of the cylinders, dragging the mainstraps E, which take the chains along with them, and the vessel is raised on the cradle of swing beams, as represented in Fig. 1060 high and dry above water, so as to allow of the inspection by the shipwrights of every part of her bottom. The cradle is supported on the platform by the pawls and racks *s r*.

When the vessel is to be released, pressure is again put upon the cylinders, and then, the escape-valves being opened, and the pawls and racks *s r* released, the cradle sinks as the water escapes from the cylinders; the traverse frames and side chock-blocks are removed, and the vessel allowed to float out.

The mode of fleeting back the rams, Fig. 1062, is to detach the side rods *h*, by drawing out the gib *i i*, and turning round the roller M, by the handle N, which supports the end of the side rod *h*. The side rod having a little play on the crosshead *d*, allows it to be passed back with ease. The clamps and boxes K K are then attached to the side rods, and the screws *j* turned by means of the bevel-wheel and pinions I and L, the motion of which is taken from the mainshaft F* of the pump-room, Fig. 1070, by putting on a clutch I*.

Another dock company at New York, is that called the *Sectional Floating Dock Company*. The docks of this company are the most powerful, being capable of lifting vessels of 2000 tons burden.

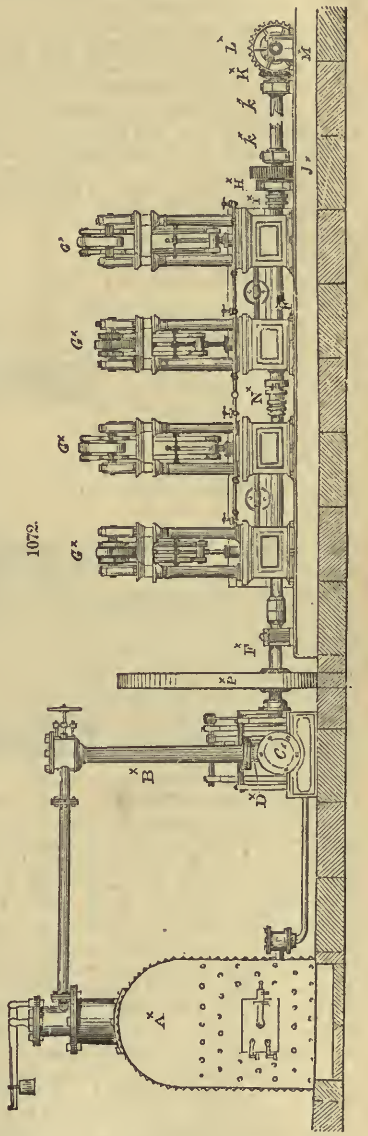
This dock is executed at a comparatively small cost, being chiefly of timber, and being more powerful and efficient, is esteemed preferable to all the others.

The entire safety of this system is another advantage, as it is scarcely possible that an accident can arise either to the vessel raised or to the workmen employed in the repairs. The dock, also, instead of being fixed, and in one position, like the marine railway and screw-docks, may be towed to any vessel within a convenient distance.

Suppose that a ship is sunk, say in 5 fathoms water, it may be raised to the surface by hogsheads, or slung by any of the usual modes; and once got up to the surface, the sectional floating dock can be readily introduced beneath it, and the whole towed together to the landing or shipwright's wharf.

Although this dock has many facilities, it has, however, some of the inconveniences of dry-docks, as the vessel is hidden between the towering sides and the machine sheds on them; and the whole forms a damp structure of wood.

The sectional floating-dock derives its name from its consisting of distinct sections of timber framing in the form of a floating-dock, into which ships can enter. In the sections on each side are balance-tanks, raised and lowered by means of a rack and pinion, and also tanks, which, by being filled with water, cause the dock to sink, and by the water being pumped out, enable it to be raised to any required height out of the water, the ship resting on the platform within. On the top of the sections is machinery for working the racks and pinions and pump-work.



1072

Such is the general principle of the contrivance. Now to detail the construction. According to the size of the vessel to be raised, any number of sections, more or less, may be used, as convenience suggests. Each section is 92 feet broad externally, and 64 feet internally, and 23 feet long; the total length of the seven sections being 165 feet. The section is 38 feet high externally, exclusive of engine-house, and 28 feet high internally to the top of the standards. The dock, it will be seen, is neither more nor less than a large floating timber vessel, and is constructed of beams strongly bolted together.

Each section may be considered as consisting of three parts—two lateral scaffoldings or framings of standards within which the balance-tanks run, and a central platform connecting them. The object of the lateral framing is to enable the balance-tanks B to be run up and down, and to prevent the machines from coming in contact with the water. Each lateral portion consists of two external standards 36 feet high and 12 inches square, and of four internal standards 37½ feet high and 12 inches square. These standards are at the bottom secured to the outside truss-girders, and on their tops carry a platform on which the engine apparatus is placed. The standards are bound together by proper tie-pieces, and are further secured to the outside truss-girders by a 12-inch beam, 44 feet long. At the bottom of each lateral framing is a flooring on which rests a balance-tank B, 19½ feet long, 10 feet broad, and 8 feet deep, being of a capacity of about 1,500 cubic feet. The total capacities of the fourteen tanks would therefore be 21,000 cubic feet. Besides these are water tanks within the platform in which the pump-rods work.

The platform is about 10 feet deep, and on the upper surface consists of two outside truss-girders

being about 70 feet long and 17 inches across, composed of two beams scarped together. Between these are a cross-beam, 7 inches square in the centre, secured to the keel-beam; and a cross-beam on each side 9 inches square, for carrying the chock-blocks, and secured to the keel-beams. These cross-beams rest on joists or tie-pieces 10 inches square. In the centre across are the two keel-beams, 24½ feet long and 12 inches square, and which carry five keel-blocks. This upper platform rests on the foundation truss-girders, by means of posts and timbers scarfed in, and is further secured by four stout iron ties. The bottom truss-girder is 93 feet long, and formed in three portions, well scarped, tied, and bolted together. These bottom truss-girders extend under the lateral framings, knitting together the whole structure.

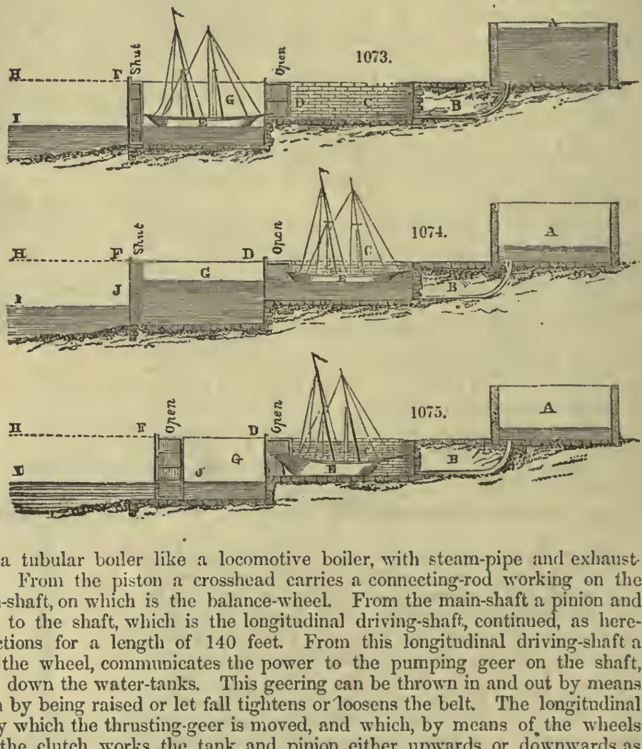
The sections are connected together, in case of need, by the double tie-beams, which can be readily slipped out, by withdrawing the nuts and screws by which they are secured.

On the cross-beams on each side is a rack and pawl, enabling the chock-blocks to be readily moved, and secured by means of tackle. The chock-blocks are 4 feet high and 3 feet 9 inches wide. These receive the bottom of the ship; but in order to steady the sides there are side supports on each side, worked by block and pawl, so as to make the ship firm to the inner standards.

The object of the balance-tanks is to keep the dock steady and in an upright position. They contain no water, and it is only necessary to keep them depressed to the level of the water, either in sinking or raising the dock, and their resistance keeps the whole dock, with the ship, perfectly steady.

The lateral framings are furnished with two stationary spuds 34 feet high and 7 inches square, provided, on one side, for 27½ feet, with a rack-plate. This spud is secured into the framing at top and bottom, and is for the purpose of working the tank up and down by machinery, subsequently to be explained, and part of which is seated on the top of the tank B. Each lateral framing is also provided with a ladder, and an upper stage for the workmen.

On each side of the centre section is an engine-house, which contains the machinery for working the thrusting and pumping apparatus, and from which shafts run along the sections on each side. It should be observed that the machinery on all the sections is covered in.



1073.
1074.
1075.

The engine-house contains a tubular boiler like a locomotive boiler, with steam-pipe and exhaust-pipe, cylinder and valve-box. From the piston a crosshead carries a connecting-rod working on the crank, which drives the main-shaft, on which is the balance-wheel. From the main-shaft a pinion and bevel-wheel carry the motion to the shaft, which is the longitudinal driving-shaft, continued, as hereafter explained, along the sections for a length of 140 feet. From this longitudinal driving-shaft a wheel, working by a belt on the wheel, communicates the power to the pumping geer on the shaft, crank, and pump-rod, running down the water-tanks. This geering can be thrown in and out by means of the moveable pulley, which by being raised or let fall tightens or loosens the belt. The longitudinal shaft also works the shaft, by which the thrusting-geer is moved, and which, by means of the wheels and pinions, put on or off by the clutch, works the tank and pinion either upwards or downwards as may be required. The shaft is connected at each end by means of the universal joint, and by the small circular shaft, with the longitudinal shafting on the end sections. By this means the different sections may be placed at such distance from each other as the length of any ship may render necessary. It is to be observed, that a necessity constantly occurs for sinking one or more sections lower than the others. This is also provided for by the slip and universal joints.

The thrusting-geer for raising and lowering the tank takes its motion, as mentioned, from the shaft, by means of the bevel-wheel, which moves the pinion, the head of the square vertical shaft. On this shaft is a moveable socket, with a square hole in it, and four friction rollers, so that the vertical shaft may easily pass through it. Beneath the friction rollers is a pinion working into the bevel-wheel. This bevel-wheel is on the horizontal shaft, secured into a framing on the top of the platform of the tank. The horizontal shaft carries a worm, working into the worm-wheel, the shaft of which carries a pinion at each end, working into the spud, which is kept in geer by the friction roller. The number of spuds is twenty-eight, four on each section, or two for each tank. On the end sections the machinery consists merely of the longitudinal shaft, the thrusting and pumping geer.

The process of taking a ship into the sectional floating-dock is as flollows:—The dock is sunk to any required depth by opening the gates or valves with which each water-tank is furnished, and the dock necessarily sinks. The dock sill being at the required depth, the ship is then introduced between the

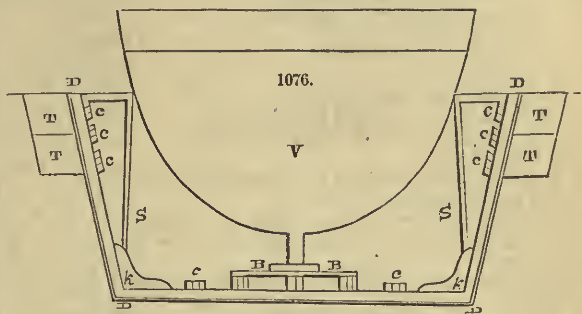
vertical side-framing, rests on the keel blocks, and when supported on the sides by the chock-blocks and side-supports is ready for lifting.

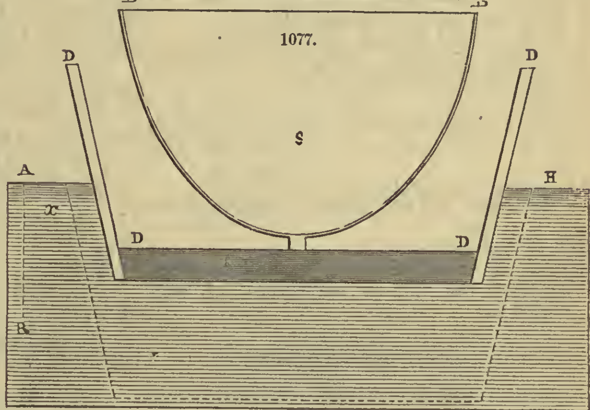
The valves which have previously admitted the water into the water-tanks are now closed, the water is pumped out, and the air again fills the tanks, and they rise, bringing with them the vessel to the height necessary for repairs.

The vessel is taken out of dock by a repetition of the process of admitting water into the tanks.

The patent is for the general arrangement in the construction of the side-balance tanks.

Besides these several kinds of dock apparatus in actual working at New York, many plans have been proposed in the United States, and nearly fifty patents taken out within the last twenty years, for the invention and improvement of slips, marine railways, floating, and other docks.





In 1826, Captain Thomas Caldwell proposed a system of dock without pumping power. He proposed to construct a dry-dock of about twice the usual length; to be divided into two compartments by gates situated near the centre of the structure; an additional pair of gates being placed at the extremity, opening a communication with the harbor. The vessel was to enter the first compartment, the external gates being closed, and the internal gates being opened. The bottom of the second compartment would be above the level of the water in the first or outer compartment, and consequently at this period dry. The water was then to be permitted to flow from an elevated reservoir, through a pipe, into the dock. When by this means the surface was sufficiently elevated, the vessel was to be hauled into the second compartment, constructed in all respects similar to a common dry-dock. The central gates being closed and secured, the water was to be discharged into the adjacent harbor, Fig. 1073.

In 1826, Commodore Barron, of the United States Navy, invented a floating dock in the form of a large scow. (See Fig. 1076.) It will be seen that it is a large flat-bottomed boat, furnished at one end with a pair of gates, and having on each side two air-tight trunks T T, to preserve the buoyancy of the dock when filled with water. In the sides are port-holes, like those of a man-of-war, so as to allow of being opened when the dock is above water, and admitting light and air, and the introduction of materials. In case of being used in salt-water, it was proposed to copper the outside of the dock as high as the float-line of the dock when it contained no water. As the dock would not be exposed to much friction, the Commodore was of opinion that very thin sheets of copper might be used.

When the gates are open the dock fills with water, and sinks to a depth sufficient to allow vessels to enter therein, and of course to displace their weight of water from the dock, when the gates are closed and secured. The vessel is then shored, and secured by the shores N and S in the usual way. The water is next to be removed from the docks by common pumps, the Archimedean screw, or by a pump forcing the water out through the bottom, which latter plan was preferred.

Letters D D D, Fig. 1077, represent the floating dock containing the vessel S. H A is the surface of the water in the harbor, which would coincide with the surface of the dock, supposing it to be sunk to the dotted line, which is its situation when full of water. This depth is also supposed to be 20 feet, or equal to A B. At the commencement of the operation of pumping the water from the floating dock, it resembles the common dock, in not requiring any power to exhaust it; but as the pumping proceeds the dock becomes lighter, and of course the bottom does not remain in the same relative position to the surface of the water in the harbor, but rises in proportion to its buoyancy.

In the figure the dock is represented as having risen. It is now immersed to the depth of about 5 feet. It is not necessary to remove the water from the space occupied by the ballasting, shaded dark in the lower part of the figure. As the water is forced out through an aperture in the bottom, the greatest resistance to be overcome is equal only to the pressure of a column of water equal in height to the line A B, (5 feet;) half of this, or $A\,x = 2\frac{1}{2}$ feet, will be the average resistance during the whole operation. Therefore, the power required to remove the water from the floating dock by a forcing-pump, will be to the power required to remove the water from a common dry-dock on the usual plan, as, $2\frac{1}{2} : 10$, or as $1 : 4$; viz. as $A\,x$ Fig. 1077 $=$ to $2\frac{1}{2}$ feet is to $A\,x$ dry-dock $= 10$ feet. If, however,

lifting or forcing pumps be employed to pump the water up, and discharge it over the sides, then, of course, the same power will be required for Barron's dock as for the fixed dock.

Commodore Barron's dock was proposed to be moored in a slip between two wharves or breakwaters, to flank and protect it from injury, and with a raft or floating breakwater moored in front of the dock-gate, to preserve it from storms.

Literal References.

The Patent Slip.

Fig. 1039. Elevation of the slip.
1040. Ground plan of the slip.
1041. Section on sea side.
1042. Section on land side,
A. Ground line.
B B. Sidewise, laid on piles, *c c*.
C. Midway, with rack *a* and pawl *b*.
D D D. Carriage cradle, or frame of timber.
D*. Keel beam.
E E. Cross-pieces of timber, with rack and pawl. The cross-pieces are moveable.
F F. Sliding or chock-blocks, working on the rack of the cross-pieces E E, and provided with a rope *m*.
G G. Cast-iron rollers, running on a rail on the ways B B C.
h. Block hooking on to carriage D D.
i. Chain attached to block, and working on
H. Capstan-wheel and pinion, or other purchase, firmly bedded on a large stone.
I I. Shores.
j j. Iron guides turning upon a pivot, and made by means of the tackle *k* to fit under the ship's stern.
k k. Ropes for hauling up guides or crutches.
l l. Iron guides and oblique braces for the forefoot of the vessel.
K K. Vessel on the slip.
m m. Ropes of the sliding-blocks, which are taken on board the ship for the purpose of being hauled in.

The Marine Railway, New York.

Fig. 1043. Elevation of railway, with vessel on the slip.
A A. Piles.
a. Windlass loft.
b. Hauling-up geer.
c. Chain attached to the carriage.
C. Vessel supported by the shear-shores on the carriage.
d d. Shear-shores.
Fig. 1044. End view of railway.
A A. Piles.
a a a. Midway and sidewise.
b b b. Cast-iron sheaves or trucks, flanged, and running on cast-iron rails.
c c. Timber framing or sill of the carriage.
d d. Cross-piece of timber.
e e. Bilge levers.
f f. Shear-shores.
g g. Scaffold posts.
Fig. 1045. View of the bilge levers and shear-shores.
a. The ways.
b. The rail.
c c. The cast-iron sheaves or trucks.
d d. The sill of the framing.
e. The plank.
f. The cross-tie or piece.
g g. The hollow coin-blocks or side-blocks.
h. The shear-shore.
i. The screw.
k. The windlass.
l. The bilge lever.
m. The prop for supporting the bilge lever.
Fig. 1046. Side view of the bilge levers and shear-shores.
Figs. 1047 to 1053. The lifting-planes, shown in detail.
a. The ship's keel.
b. The upper block of the lifting-planes.
c. The under block of the lifting-planes.
d d. The wedges.
e f. The block in different points of view.
Fig. 1054. The battering-rams.
g g. The battering-rams.
Fig. 1055. The improved dowelling-bit.
a. The chisel, as in the old implement.
b. The cutter, as in the old implement.
c. The gouge, improved.
d. The screw, improved.
Fig. 1056. The New York chain.
Figs. 1056 and 1057. The under-water implements and works.
a a a a. Piles.
b. Pile standing out of water.
c c. Piles cut off to the line of the plane.
d. Pile in the process of cutting off in the diving-bell, Fig. 1058.
e. The level and bevel in the diving-bell.
f. The batten and target.
g g. The aerial plane, parallel to the intended plane.
h. The water-line.
i. Compasses.
k. The ground-line.
l. The intended plane.
Fig. 1059. Tucker's improved chain.

Elevation of Platform of Hydrostatic Dry Dock without the Hydraulic Engines.

A A. Piles in pairs, 56 feet long and 20 inches square, of best Georgia pine, shod with iron, placed 4 feet 8 inches apart, supporting the cradle.
B B. Mainway pieces, shown in detail in Fig. 1066.
C. Cylinder of the hydrostatic engine.
D. Ram or plunger-pole working in C, and attached at the outer ends to
d. Crossheads, shown in detail in Fig. 1062.
e. Friction rollers supporting *d*, and travelling on *f*.
f. Cast-iron way on which the crossheads *d* run.
E. Mainstraps of wood constituting the moving or draught-frame from which the cradle is suspended, (shown in detail in Fig. 1068.)
h. Mainside-rods from the crossheads *d* to the mainstraps E, (shown in detail, Fig. 1063.)
i i. The gib securing the mainside-rods *h*, and mainstraps E, (shown in detail, Fig. 1063.)
J. Wrought-iron straps bolted along the mainstraps E.
k k. The suspending chains.
n n. Cast-iron rollers for carrying the suspending-chains *k* to the cradle *p p*.
o o. Wrought-iron linkheads and crossbars, supporting the transverse bearers *p p*.
p p. The swinging-beams or transverse bearers of the cradle, (shown in detail in Fig. 1069.)
r r. Ratchet-plates on the mainstraps E.

s s. Wrought-iron pawl-bars, (shown in detail in Fig. 1067.)
*z**. End chock of timber to prevent the vessel from slipping riverwards.
A steamer is shown in the dock.

Fig. 1061.—*Plan of the Hydrostatic Dry Dock, New York.*

B B. Mainway pieces.
C C. Cylinders of the hydrostatic engine.
D. Ram of ditto.
d. Crossheads to which the ram D is attached.
Friction rollers supporting *d* and travelling on *f*.
f. Cast-iron way on which the crossheads *d* run.
E E. Mainstraps of wood from which the cradle is suspended.
h. Mainside-rods from *d* to E.
i i. Gib securing the mainside-rods *h h*, and the mainstraps E E.
J J. Wrought-iron straps on E.
k. The suspending chains to the transverse bearers *p p*.
l l. Wrought-iron crossbars or distance-pieces between the timbers of the mainstraps E, and in which eyes are formed to receive the adjusting-screws and nuts *m* of each suspending-chain *k*.
m m. Adjusting-screws and nuts of the suspending-chains *k k*.
n n. Cast-iron sheaves or rollers for carrying the suspending-chains *k k*.
p p. The swinging-frames or transverse bearers of the cradle carried by the suspending-chains *k k*.
q q. The traverse-frames.
r r. Ratchet-plates on the mainstraps E, on which the pawl-bars *s* work.
s s. Wrought-iron pawl-bars.
*o**. Pipes communicating with the pump-room.
w w. Keel blocks of timber.
x x. Iron rack and pawl for keeping the chock-blocks in their places.
*y**. Balks bearing the trasverse-frames *q*.
*z**. End chock of timber.

Hydrostatic Dry Dock.

Fig. 1062. Enlarged plan of hydrostatic cylinder, with the fleeting apparatus.
C. Hydrostatic cylinder 18 feet long.
D. Ram secured to the crosshead *d* by the collar *x**.
d. Crosshead.
E. Mainstraps.
h h. Mainside-rods.
i. The gib-securing the mainstraps E and mainside rods *h*.
j j. Screws for fleeting back the ram D.
K K. Clamp and box attached to the side-rods *h h*.
I I. Bevel-wheel working on the pinion L.
L L. Pinion to the wheel I.
M*. Shaft from the engine-room turning the pinions L.
M M. Roller moved by the handle N.
N. Handle supporting the end of the mainside-rod *h*.
*x**. Collar connecting the ram D and crosshead *d*.
Fig. 1063.—Elevation of the mainside-rod *h*, with the roller M, and handle N.
Fig. 1064—Cross section through the cylinder, side-rods, and mainways.

Hydrostatic Dry Dock.

Fig. 1065. Enlarged longitudinal section of one of the mainside straps E
A A. Piles.
B B. Mainway piece.
E E. Mainside straps.
k k. The suspending chain to the transverse bearers *p p*.
l. Iron crossbar or distance-piece, in which eyes are formed to receive the adjusting-screw and nut *m* of the suspending-chain *k*.
m. Wrought-iron adjusting nut and screw.
n. Cast-iron sheave for carrying the chain.
o. Wrought-iron linkhead and crossbar supporting the transverse bearers or swinging-beams *p p*.
p p. Transverse bearers or swinging-beams of the cradle.
r r. Ratchet plate on the mainside strap E.
s s. Wrought-iron pawl-bar.
u. Box in the crosshead, at the back of which is the nut *m*.
Fig. 1066. Enlarged plan of mainside strap E and pawl-bar *s*.
Fig. 1067. Enlarged section of mainside strap E, pawl-bar *s*, mainway piece B, and piles A.
A A. Pair of piles, each 56 feet long and 20 inches square, of best Georgia pine, with iron shoes, diverging from the perpendicular, at the lowest extremity, about 3 feet.
*a** *a**. 1¼-inch bolts to secure piles.
B. Mainway pieces of five logs of Georgia pine, 182 feet in length by 2 feet 10 inches in thickness and 4 feet 10 inches in breadth, with piles A A mortised in.
E E. Mainside straps, constructed of three pieces of Georgia pine.
r. Ratchet-plate or rack on the mainside strap.
s. Wrought-iron pawl-bar.
*z**. Trenails of locust wood.
Fig. 1068. Elevation of swinging-beams or trans verse bearers *p p*.
k k. Suspension-chains of iron.
p p. Swinging-beam or transverse bearer of oak, strapped together by the wrought-iron straps *v*.
q q. The traverse-beams of timber for supporting the chock-blocks *t*.
t t. Chock-blocks of timber for supporting the sides of the vessel.
v v. Wrought-iron straps.
w w. Keel-block of timber.
x x. Iron rack and pawl for keeping the chock blocks in their place.
y y. *z z*. Blocks and tackle for working the chock blocks.
Fig. 1069. Plan of the swinging-beams *p*.

Fig. 1072.—*Hydrostatic Dry Dock. Front Elevation of the Pump-Room.*

A*. Tubular boiler.
B*. Steam-pipe.
C*. Cylinder.
D*. Valve-box.
E*. Connecting-rod from cylinder C* to shaft F*.
F* F*. Mainshaft working the geering.
G* G*. Cranks from shaft *k** to the pump-rods each crank working two pairs of pumps.
H*. Pinion on shaft F*.
I*. Clutch for putting pinion H* in geer with wheel J*.
J*. Wheel on shaft *k**, for transferring motion to the geering for fleeting back the ram.
*k**. Shaft bearing the wheel J* and pinion K*.
K*. Pinion on shaft *k** working with the wheel L*.
L*. Wheel for transferring the power at right angles to the shaft M*.

M*. Shaft turning the pinions L L.
N*. Tank. P*. Balance-wheel.

Hydrostatic Dry Dock.

Fig. 1070. Plan of the pump-room.
A*. Tubular boiler. B*. Steam-pipe.
C*. Cylinder. D*. Valve-box.
E*. Connecting-rod. F* F*. Main shaft.
G* G*. Cranks working the pump-rods *p* p**
H*. Pinion on shaft F*.
I*. Clutch for putting fleeting apparatus in geer.
J*. Wheel on shaft *k** for transferring motion.
*k**. Shaft bearing the wheel J* and pinion K*.
K*. Pinion. L*. Wheel on shaft M*.
M*. Shaft turning the pinions L L.
L L. Pinions working in geer with the wheels I I.
I I. Wheels on the spindles of the screws *j j*.
j j. Screws for fleeting back the ram D of the hydrostatic cylinder.
N*. Tank. O*. Chimney-flue.
P*. Balance-wheel 10 feet diameter.
*o**. Pipes communicating between the tank and the hydrostatic cylinder C C; each set of pumps provided with separate stop-cocks.
Fig. 1071. Side elevation of the pumping apparatus.
F*. Main shaft.
G*. Crank for working the pump-rods.
*p**. Pump-rods.

Barron's Floating Dock.

Fig. 1076. Barron's floating dock. D D. Dock.
k k. Knees at the angles bolted firmly to the horizontal or upright timber D D.
c c c. Horizontal or inclined slips of ceiling, running fore and aft, into which the timbers D D are inserted.
T T T. Air-tight trunks. V. Vessel in dock.
S S. Waleshore supporting the ship V.
h h. Horizontal shores. B B. Keel-blocks.
Fig. 1077. Barron's floating dock raised out of the water.

Caldwell's proposed Dry Dock.

Figs. 1073, 1074, and 1075. The dock, with vessel entering, floating, and lying. A. Reservoir.
B. Pipe communicating with the inner-dock C.
C. Inner-dock. D. Inner-gate. E. Vessel.
F. Outer-gate. G. Outer-dock. H. Ground level.
I. Level of the water in the harbor.
J. Level of the water in the dock.

DOCK. See Floating Sectional.

DRAWING MACHINE.—*Lowell Machine-Shop.*

Fig. 1106 is a front elevation, with cans A removed.

Fig. 1107 is an end elevation, showing geered end of rolls.

Fig. 1108 is an end elevation, showing pulley end of rolls.

A is the tin cans into which the slivre is deposited.

B is cast-iron end, or support for frame.

C is the plungers or crowders that press the slivre into the tin cans A A, after it has passed through the rolls.

D is an upright shaft for driving-cam b^1, and giving a rotary motion to the cans A A.

E is a stand attached to *r* for support to upright shaft D.

E^1 is a pair of calender-rolls, resting upon the table D^1, by means of stands J, through which the slivre passes before entering the tin cans.

G is a bushing or bearing-in floor, to guide lower end of upright shaft to plungers.

G^1 G^1 and W are weights for weighting top rolls.

D^1 is a table of iron, sometimes of wood, to support calender-rolls.

Z Z Z Z are steel rolls fluted: there are three and four, and sometimes five, rolls, which increase in velocity from the first to last sets, making the draft.

S^1 are stands to support rolls Z Z, &c.

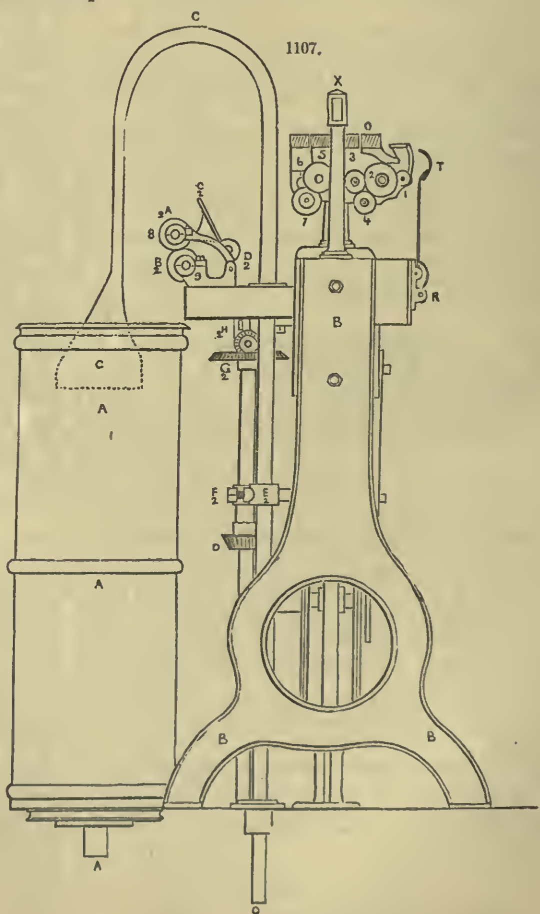
A^1 is a stand to support the end of driving-roll.

X X are stands to hold belt shipping-bar, which is wood, sliding in the stands.

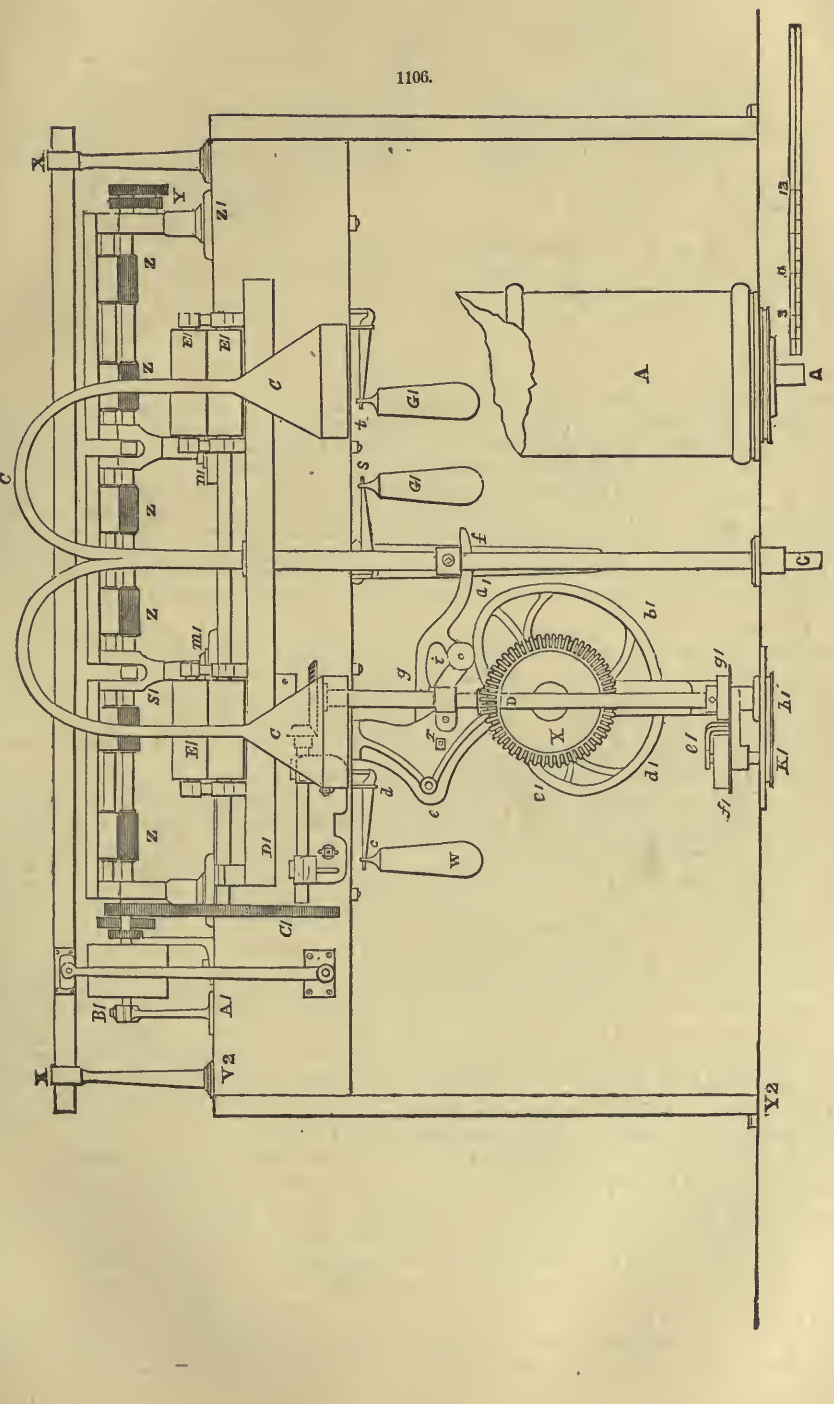
X^1, bevel-geers on cam-shaft.

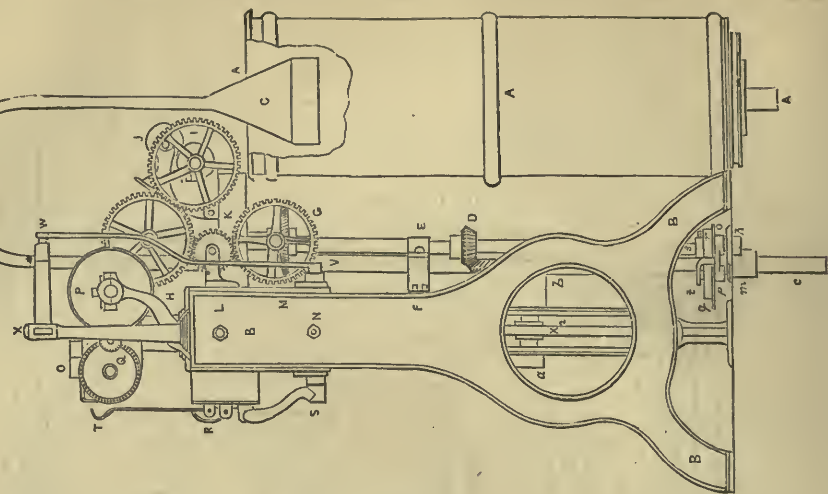
b^1, cam for producing up and down motion on the crowders C C.

1107.



1106.





1108.

K^1 is a mangle-wheel, which gives an alternate circular motion to the cams A, which are driven by a pulley and shaft $f\,l$, which has a pinion on the lower end geering into the mangle-wheel. The pulley f^1 is driven by a belt from the upright D. i is a friction-roll attached to a lever g, which raises and falls the crowders $c\,c\,c$. Y, Fig. 1106, represents the edge view of roll-geers. O O, wooden clearers, which are covered with cloth for clearing top rolls from waste cotton. P are driving-pulleys, tight and loose. Q, geers on back roll. S is an arm operated by a stop-motion R T, which moves arm W, that is attached to shipper-bar in stands X X. T is a light tin trumpet, over which the slivre passes in entering the rolls. In case the slivre breaks or runs out, this trumpet falls back, which throws out a ratch, and lets the slide, by means of a spiral spring, press against arm S, which works arm W, and stops the machine. The roll-geers are made to vary in size to suit the operator on No. of yarn which may be required.

DRAW-BORE. The pinning a mortise and tenon, by piercing the hole through the tenon nearer to the shoulder than the holes through the cheeks, from the abutment in which the shoulder is to come in contact. *Draw-Bore Pins.* Pieces of steel in the shape of the frustrum of a cone, somewhat tapered, and inserted in handles with the greatest diameter next to the handle, for driving through the draw-bores of a mortise and tenon, in order to bring the shoulder of the rail close home to the abutment on the edge of the style: when this is effected, the draw-bore pins, when more than one are used, are taken out singly, and the holes filled up with wooden pegs.

DREDGING AND DREDGING MACHINES. Dredging is effected in various ways; either by drags, or scoops, or rakes, or machines. There are two sorts of hand-drags, one for raising mud, the other sand: the first consists of an iron box pierced with holes, open in front as well as at the top; to this is attached a slightly flexible handle, of a length proportionate to the depth it is to work in: when this is made use of, the men in a boat make the iron box enter the sand, sustaining the handle on the shoulder, and when it is filled they raise it, and if there be any large stones, they are disengaged by means of hooks: a man will raise in this manner, where the depth is not more than 4 or 5 feet, a cubic yard in the course of a day, and sometimes more.

The Drag for Mud is differently formed; it is an iron ring, to which a canvas bag is attached, by passing a cord through holes made in the ring purposely to receive it: that point of the iron rim which is intended to touch the ground and enter the mud must be sufficiently strong: two men in a boat or punt are required to manœuvre it, and in the course of a day they will raise from 12 to 14 cubic yards, if the depth does not exceed 6 feet: when the boat is made use of, it is first moored in such a manner that it cannot drift; such a drag allows the water to flow out of it, and retains only the solid matter.

The Louchette, a kind of spade, or a collection of them, is used for cutting or extracting turf under water, without the necessity of first pumping it dry: this consists of a light iron frame, which is armed all round with a cutting-blade, in length about 3 feet; the part between it and the handle is open, being formed of four horizontal rods, and two vertical ones; these receive the turf after it is cut and detached, and enable the workmen, by means of a rope and windlass, to pull it up; these cutting instruments have a variety of forms given them to adapt them to the peculiar work they may have to perform.

The Box Shovel consists of an open box fixed at the end of a long handle, usually made of iron; the cutter traverses in a groove, and is worked by another handle; by this the turf is cut and detached, and each successive piece falls into the box: as many as four turfs may be thus drawn up at one time.

Dredging machines have been constructed in various ways, and of iron or wood, according to the nature of the service. Some machines have been arranged so that the system of chain and buckets should work through a channel in the middle of the vessel; others with one system on each side; and others with the buckets working over the extremity of the vessel. But, in general, the modern practice is to place the machinery towards one extremity of the vessel, to allow of the working of the ladder (which holds the buckets) freely on either side of the vessel. By this arrangement barges can be laid along both sides of the vessel, and the material raised by the machine be taken away more easily.

Perhaps the most popular form of machine for dredging purposes is the spoon dredger; similar in all essential particulars to the excavator invented by Otis, and used for land purposes; when placed upon a proper barge, with strong posts at either end, which, sliding in grooves, may be lowered vertically to serve as anchors. This machine is one of the most economical in use, and as a full description of it is given under the head of excavator, we shall confine ourselves to the chain and bucket dredging machines.

The best adapted boilers and engines for dredging purposes, are those upon the marine principle, as in them compactness and stability are combined; and for which reasons, they of that description are invariably applied; but in practice it is found disadvantageous to the profitable working of the machine, if the engine be not of a proportionate power to the depth of water, the buckets of a suitable number, and the bucket-frame of sufficient length to lie at a proper angle. Hence the following arranged proportions are annexed as the best adapted for working at or about the various specified depths from which the material is to be raised:—

Nominal Power of Engine.	Length of Bucket-Frame.	Number of Buckets.	Depth of Water in feet.
20	59½	34	18
25	63	36	20
30	78¾	45	25

The boat requires little or no peculiarity of form, otherwise than that of proper stability; it must be strong and well put together, or a constant tremulous motion is created by the action of the machinery, and the proper effect of the machine in a measure destroyed. It must also be of magnitude sufficient for the receiving of the machinery with a proper clearance for the buckets, according to the depth of water, and different positions in which, on that account, they are so frequently required.

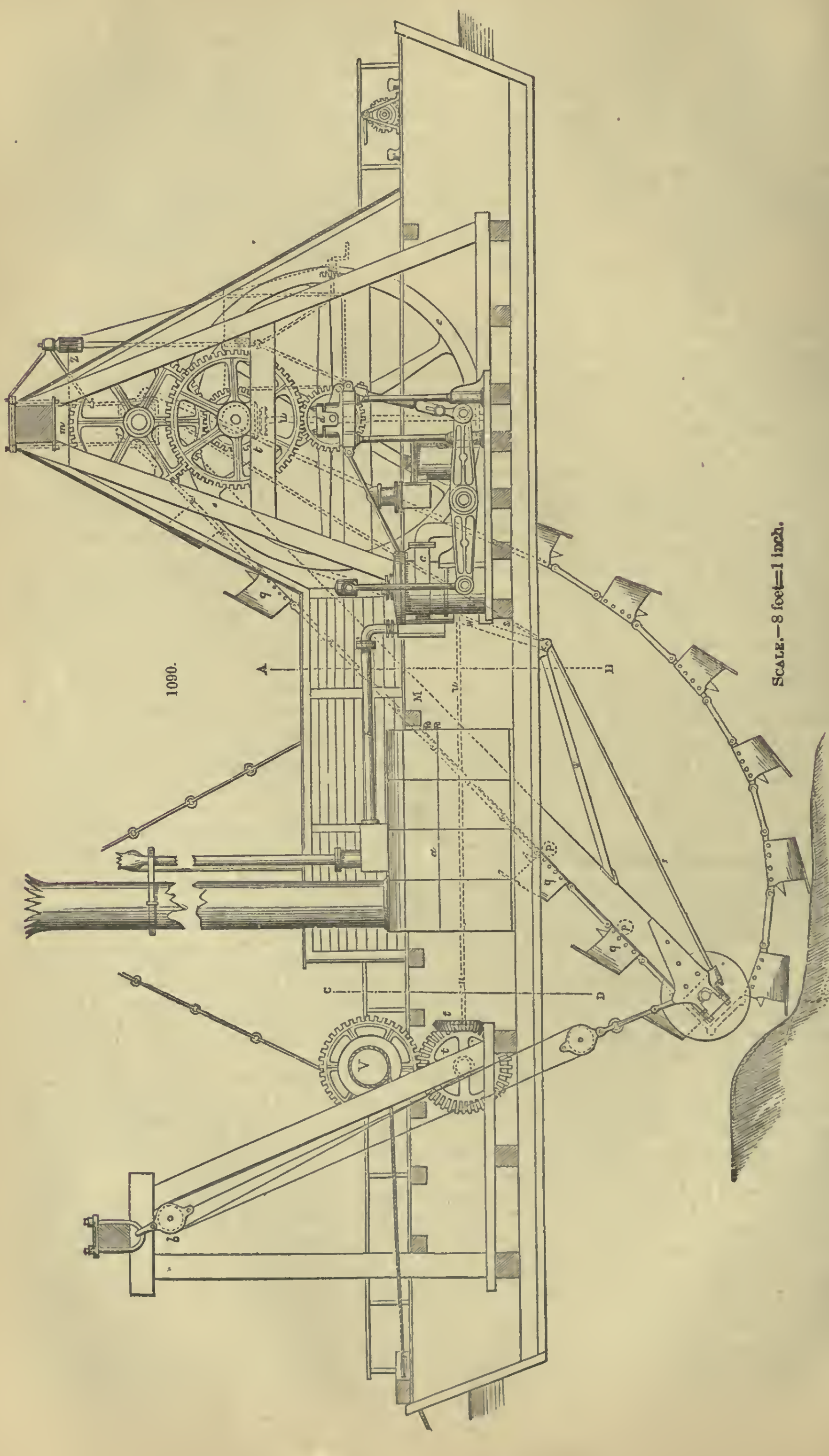
Description of the Machinery in the Dredging Vessel constructed by Summers, Groves and Day.—The objects which were chiefly kept in view in arranging the machinery of this dredging-engine, were simplicity of construction with efficiency and facility in adapting it to the work it would have to perform; and after some consideration, it appeared to the makers that a marine steam-engine, with side-beams, was the best kind of engine for this purpose, as it enabled them to convey motion to the buckets with less wheel-work, shafting, and machinery than is generally required in dredging-engines, whose works are frequently complex, and require considerable skill in their management.

Figs. 1090 to 1099, show an elevation, plan, and section of the vessel and machinery.—*a* is the boiler, constructed with internal fire-places and flues similar to the boilers commonly used for marine engines. *b*, steam-pipe leading from the steam-chest on the boiler to the engine. *c* is a condensing engine of 20 horse power, the cylinder being 27 inches diameter, and the length of stroke of piston, 2 feet 9 inches. The engine is constructed with side-beams on the marine principle, and the motion is communicated to the fly-wheel shaft *d*, by a connecting rod in the usual way. *e* is the fly-wheel. *p* is a friction-hoop, which fits lightly around a drum or sheave keyed fast on to the fly-wheel shaft. The use of this contrivance being to prevent accidents to the machinery, in case the buckets should get entangled with any thing during the process of dredging, as when the resistance increases beyond what is necessary for raising the soil, the drum or sheave slips round inside the hoop, and the buckets cease to work, whilst at the same time the steam-engine may continue its motion without injuring the machinery. *g* is a pinion bored to fit the fly-wheel shaft, (but not keyed fast to it,) having two strong stops or carries cast on one side of it, which come in contact with corresponding stops on the wrought-iron ring or hoop. *h* is a spur-wheel which is driven by the pinion *g*. *i* is a pinion keyed on the intermediate shaft, which drives the spur-wheel *j*, keyed on the tumbler-shaft. *l l* are clutch couplings for the purpose of connecting one or both sets of buckets to the steam-engine, or disengaging them when required. *m m m m* are cast-iron carriages, forming joints or hinges for supporting the bucket-ladders independent of the tumbler-shafts. *n n n n* are the tumblers over which the chain and buckets work. *q q q q*, &c., are the buckets made of boiler-plate, and bolted securely to the links of the chain in a peculiar way, more clearly described in figs. 1094 to 1096, where the buckets and links are shown on an enlarged scale, and in which, on the front of the buckets, will be observed a kind of spade that is of steel, and attached to the bucket by rivets, consequently easily renewed at any time when worn away: the bucket-chain runs on cast-iron rollers *p p*. The bucket-ladders are made partly of wood, having wooden sides with cast-iron king-posts and transverse trusses; with wooden struts and wrought-iron tie-bolts, with screws at the ends, so that they may be tightened up when required. These ladders are remarkably strong, with comparatively light materials.

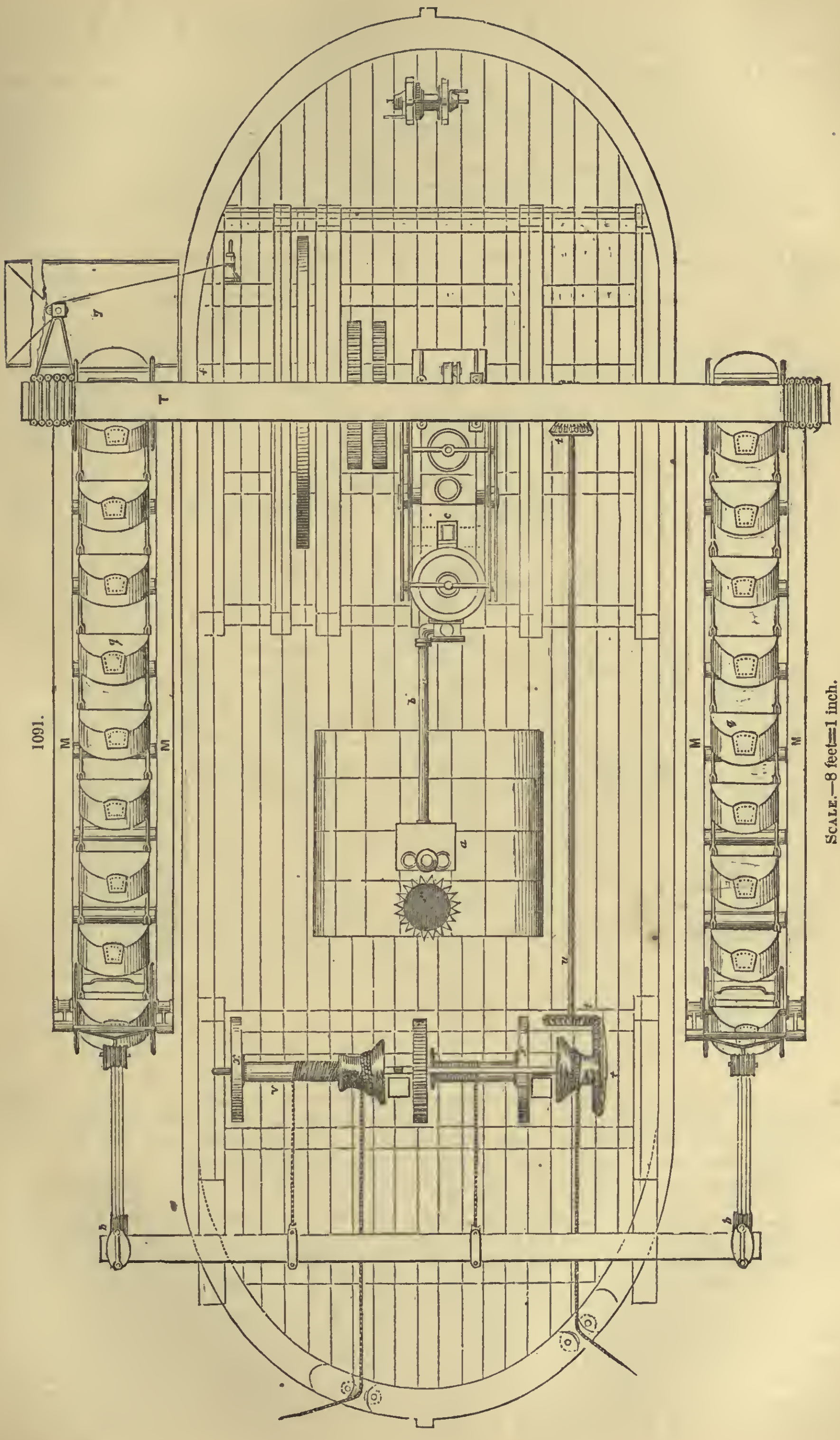
The spout *g* is of wood, lined with sheet-iron, and has a joint at *r* to allow of the punts or barges being equally loaded on both sides without turning them round. As when the outer end of the spout is raised by means of the purchase *z*, the soil will escape at *r*, near to the side of the barge which is close to the dredging-machine, on lowering down the outer end of the spout, the soil will be carried over to the other side of the barge, thus insuring its being equally loaded. The bevel-wheels *t t t t tt* and shafts *u u*, figs. 1091 and 1092, convey the motion from the steam-engine to the apparatus on deck for propelling the vessel to and fro, raising or lowering the bucket-ladders, &c. The ladders are raised by chains passing round the barrels *v v*, and working in the sheaved blocks *b b*, which are suspended from the timber framing. The operation of raising the ladders is effected by connecting the barrels to the shafts by the clutches *w w*, which are worked to and fro by levers that pass through the deck of the vessel. When the ladders require lowering, the clutches are drawn back and the ladders run down of themselves to any depth which is desired, being regulated by a brake attached to the drums at *x x*, as shown in figs. 1091 and 1093.

The apparatus for propelling the vessel to and fro is fixed on the deck. *y y* are two curved cast-iron barrels. By taking two or three turns of a rope or chain round these barrels, one under and the other over, one of the ropes will draw the vessel ahead, whilst the other pays off the slack, and *vice versa:*

1090.



SCALE.—8 feet=1 inch.



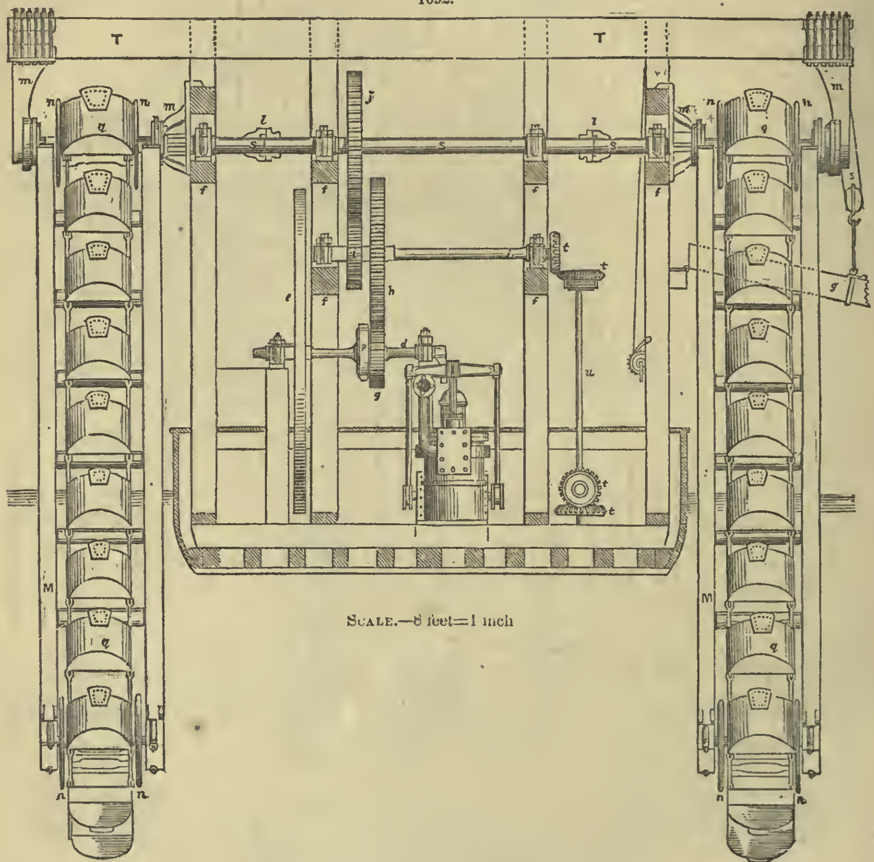
1091.

SCALE.—8 feet=1 inch.

or by putting both ropes or chains the same way round these barrels, they will both act in pulling the vessel in the same direction. It should be named that there is a friction-sheave placed between the propelling machinery and the steam-engine, similar to that which is fixed upon the fly-wheel shaft, to prevent the chains or ropes being broken in case of any obstructions.

The bucket-ladder, Fig. 1090, is composed *partly* of timber framing; the main timber M (which runs the whole length) being eighteen inches deep and eight inches broad, connected by strong cast-iron crosses, (*not* shown in the drawing, as it was thought they would only confuse the adjacent parts.) To give it strength to bear the weight of the buckets with their contents, it is furnished with a cast-iron king-post k, having two inch tie-bolts $s\,s$ connected to its lower extremity by a single and double forked joint, through which joints and the king-post a pin passes, thus firmly uniting them at this point. The *other* ends of the tie-bolts pass through snugs, cast on the top and bottom carriages at ends of ladder, and are

1092.



SCALE.—8 feet=1 inch

furnished with a screw for the purpose of setting them up, by means of a nut, should they at any time become slack. There are also two *wooden* trusses $w\,w$, which take the strain of the framing, midway between its centre and either end. This ladder is found sufficiently strong, and well adapted for sustaining a heavy weight; at the same time it is extremely light in appearance.

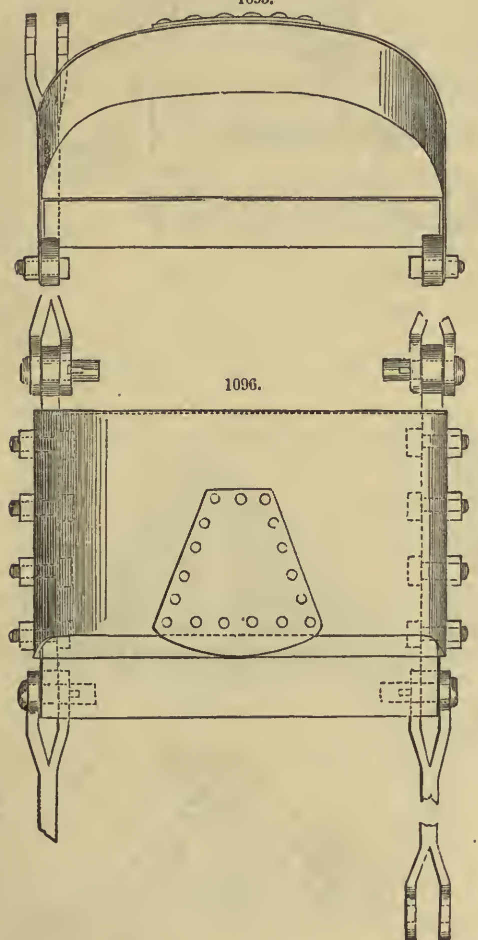
The buckets are made of boiler-plate, the back being half an inch thick. The back plate rises considerably above the other parts of the bucket, and slopes forward at an angle of about 25° towards the front or lip of bucket, for the purpose of retaining the soil and preventing its being spilled during its progress, after receiving it from the excavation, until it deposites the same in the barges alongside. The form of this back plate prevents a great loss of mud or other material, which would otherwise be the result, and consequently a loss of time would follow, and the quantity of soil delivered would not be adequate to the power of the steam-engine. All the other parts of bucket, (exclusive of the back plate before mentioned,) are three-eighths of an inch thick. The buckets at present dig to a depth of 24 feet, but greater depths may be obtained by merely lengthening the timber framing of ladder, and adding a greater number of buckets and links, proportionate to the extended length.

As the bucket-links are given in the same drawing with the bucket, further description is deemed superfluous; it may, however, be remarked, that the links pass over the tumblers with perfect ease, and *without noise*, owing to there being no projections on their *lower* sides, as the requisite strength round the pins is carried *above* the centre of the link, and not on *each side*, as is frequently the case.

The upper or tumbler shaft *s s s*, Fig. 1092, is in three lengths, having *two* coupling-boxes *l l* fitted to them, for the purpose of working either *one* set of buckets or *two* sets simultaneously; the bearings or journals of the shafts are four in number, seven inches in diameter and nine inches in length, and working in plummer-blocks, resting on four timber frames *f f f f*. The intermediate or middle shaft *i i* has bearings five inches and three-quarters diameter and eight inches in length, working also in plummer-blocks, which rest on wooden framing *f f*; and the lower or fly-wheel shaft *d*, has bearings five inches and three-quarters diameter and eight inches in length, one bearing of which rests on the engine-frame, and the other on the timber framing. These timber frames are severally connected at their tops by a strong transverse beam T T, 20 inches deep and 18 inches broad, the *outer* ends of which support carriages (to be hereafter described) for carrying the ladders, &c. By this arrangement, and by being securely fastened at their bases, the four upright timber frames are firmly kept in their perpendicular position. The form of these frames will be clearly understood by reference to the elevation, Fig. 1090.

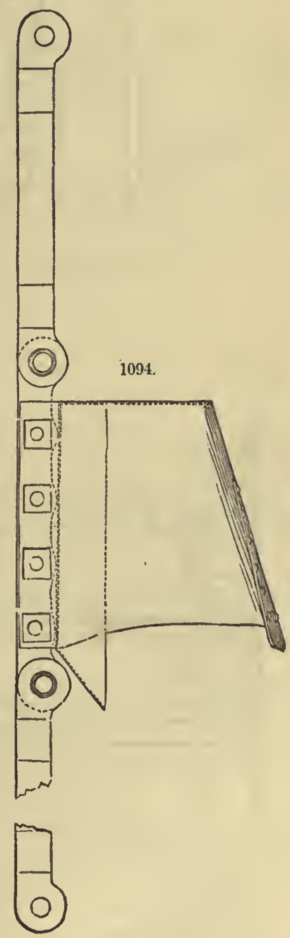
It will be seen that the outer or hanging carriages *m m*, Fig. 1092, are connected to the ends of the transverse beam in rather a novel manner; the hanging part, or part *beneath* the beam, being attached to the

1095.



1096.

1094.



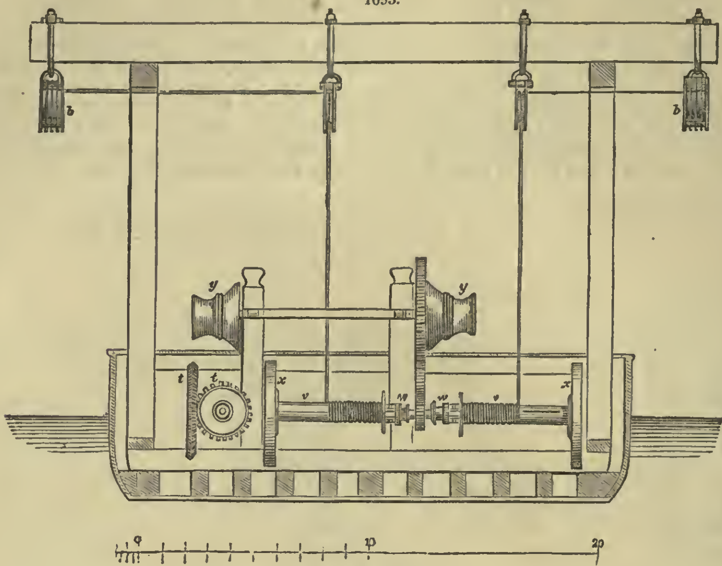
SCALE.—4 feet=3 inches.

cap or top plate by means of twelve 1¼-inch bolts, by which method it can be securely fastened to the before-mentioned beam, and adjusted so as to accommodate the tumbler-shaft, by means of packings being introduced between the cap and top of timber, and which can easily be removed at any time when required.

Figs. 1097 to 1099 consist of a detailed plan and section of top and bottom tumblers; they being of essential consequence to the efficient working of the machine, are therefore minutely delineated in an extended scale, thereby rendering the design more easily understood than by a lengthened description, which it would otherwise require. It may be observed, however, that they are of cast-iron, and the corners only being liable to derangement, are separate pieces, consequently easily removed when required.

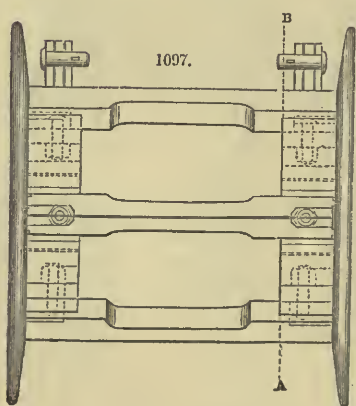
The engine with its machinery *has raised* 160 tons of soil per hour, upon an average *one* set of

1093.

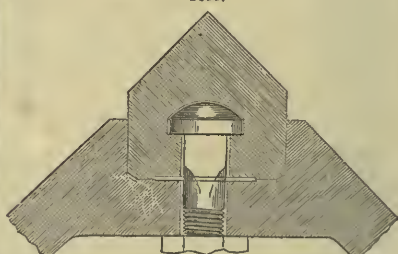


SCALE.—8 feet=1 inch.

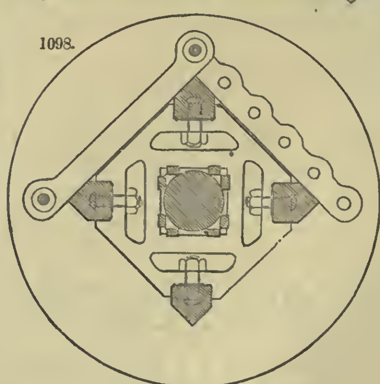
1097.



1099.



1098.



SCALE.—4 feet=3 inches.

buckets only having been employed in the performance, with a weight of three pounds and a half per square inch upon the safety-valve of the boiler.

It may be remarked, in conclusion, that the boat is supplied with a bilge-pump for discharging the bilge-water, and a deck-winch for moving the boat *by hand* when the engine is *not* working. The chain for raising the lower end of the ladder, is five-eighths of an inch in diameter, of the description called "*short* link." The draught of water is three feet six inches, with *every thing on board*, and the bottom is perfectly flat, and *both* ends are of the same form.

Specification for a Dredging Vessel of the following dimensions.

	Ft.	In.		Ft.	In.
Length of deck	80	6	Depth in hold	5	4
Breadth, extreme	22	1	Tonnage $169\frac{84}{94}$.		

The scantlings as follows:—

	In.		In.
Chine, elm, or beech	12	by	14
Floor timbers, elm or birch	$9\frac{1}{2}$	—	10
Kelson timbers, elm or birch	12	—	11

Stems, oak, sided 8 inches, moulded 9 inches.	1 deck hook, oak, at each end sided 9 inches.
Aprons, " 8 " " 8 "	1 breast hook, " " $7\frac{1}{2}$ "
Timbers, " 6 " head 6 "	Stancheons, " " 5 "
Stemson knee, at each end sided 7 "	Winch-bits " " $6 \times 7\frac{1}{2}$ "
Deck beams, oak, sided $7\frac{1}{2}$, moulded $8\frac{1}{2}$ "	Propelling gear-bits, oak $9 \times 11\frac{1}{2}$ "
Deck knees, " 5	

Plank:—

Bottom	$3\frac{1}{2}$ inch elm.	Deck	$2\frac{3}{4}$ inch yellow pine.
Outside	$2\frac{1}{2}$ " "	Bulwark	$1\frac{1}{4}$ " "
Clamps	$4\frac{1}{2}$ " "	Roughtree rail	$4 \times 2\frac{1}{2}$ " oak.
Plank-sheer	$2\frac{1}{2}$ " "		

Iron work:—

Butt bolts in bottom and sides . . . . $\frac{3}{4}$ inch.
Stemson knees and breast hooks . . . . 1 inch.

6 pair of iron knees in the wake of boiler and engine $\frac{3}{4}$ cwt., each fastened with 1-inch iron.
Deck, 5-inch spikes.
Deck fastenings all of iron.

The vessel to have both ends alike, with a break in the deck both fore and abaft.

The platform of 2-inch yellow pine round the boiler for the stowage of coals, and $1\frac{1}{4}$-inch yellow pine in the engine-room and cabins.

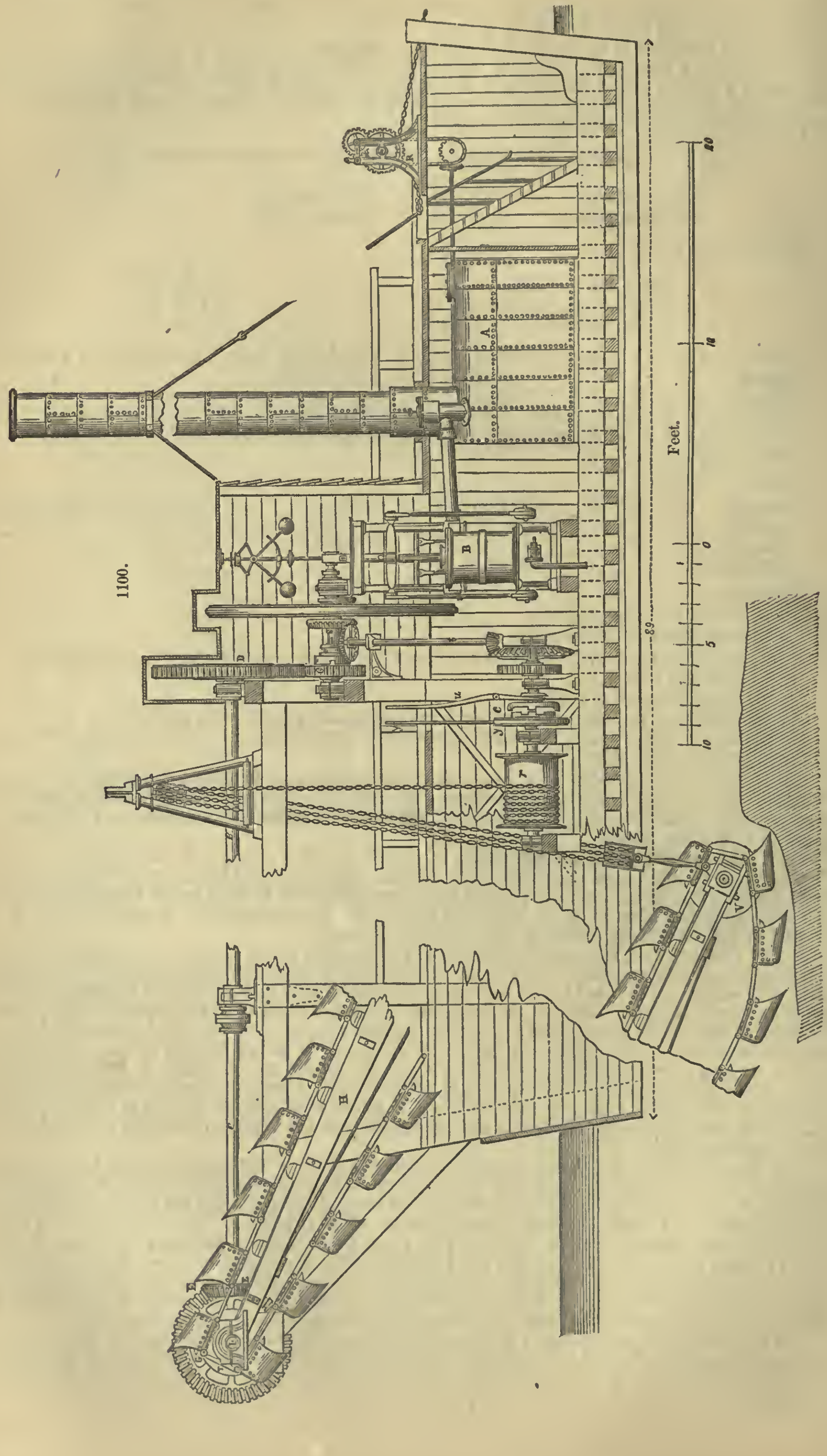
Description and specification of a Dredging-machine, constructed by Messrs. Girdwood and Co., of Glasgow, for the excavation of the River Clyde. Figs. 1100 to 1103, exhibit an elevation, plan, and section of the engine and dredging apparatus, the letters of reference corresponding in each figure or separate view of the design.

The timbers of this vessel are all exactly similar in specified variety and dimensions to that by Messrs. Summers and Co., as already minutely detailed, but the external dimensions of the vessel are a little different, viz.: entire length on deck 90 feet; extreme breadth 22 feet; height from ceiling to ceiling seven feet; and when all is on board and in complete working condition, the draught of water is about four feet. Six is the number of men employed on board.

A, Figs. 1100 and 1101, represents the boiler, and B the engine; both of which are of the usual construction adapted to marine purposes. The cylinder of the engine is 26 inches diameter; length of stroke $2\frac{1}{2}$ feet; number of strokes per minute 44; and requires about 2 cwt. of good coal per hour for the generating of a sufficient supply of steam. In effect, the engine will lift, from a depth of 18 feet, about 110 tons of mud or clay per hour, or 160 tons of sand or gravel in the same time; but in very hard ground, and intermixed with stones, no proper data can be given. The vessel is moved forward by the power of the engine, through means of the bevel-wheels, shafting, pitch-chain, &c., as shown in each design, and which communicates motion (when required) to, and by means of the double-acting winch R, and when the buckets are working in mud or clay, the vessel is caused to advance at the rate of about four feet per minute, when in gravel or sand at $2\frac{1}{2}$ feet per minute, and the number of buckets delivered is 14 in that space of time.

With regard to the movement of the buckets, motion is given to the wheels C and D by the crank-shaft S of the engine, and communicated by the line of shafting *e e e*, &c., to the wheels F and G; from thence to the buckets by the barrel or tumbler T, that being made fast upon the spindle I, which is of malleable-iron, eight inches diameter, and on which the wheel G is fixed. The small wheel C is three feet three inches in diameter; the cog-wheel D is seven feet diameter; the shafts *e e*, &c. are of cast-iron, $6\frac{1}{2}$ inches diameter in the bearings; the bevel-pinion F is two feet three inches diameter, and the bevel-wheel G is six feet, and makes seven revolutions per minute; the top or upper tumbler T has four sides, and the bottom tumbler V five; as when they are thus formed, the motion of the buckets is found in practice to work more steady, and, consequently, the effects rendered more complete.

The bucket-frame H, acting upon I as a centre, is also regulated to a proper depth of water by the power of the engine; the bevel-wheel K upon the crank-shaft S gives motion by means of the wheels *l m n*, to the barrel *r*, and round which the chain of the tackle passes, as shown distinctly in the elevation.

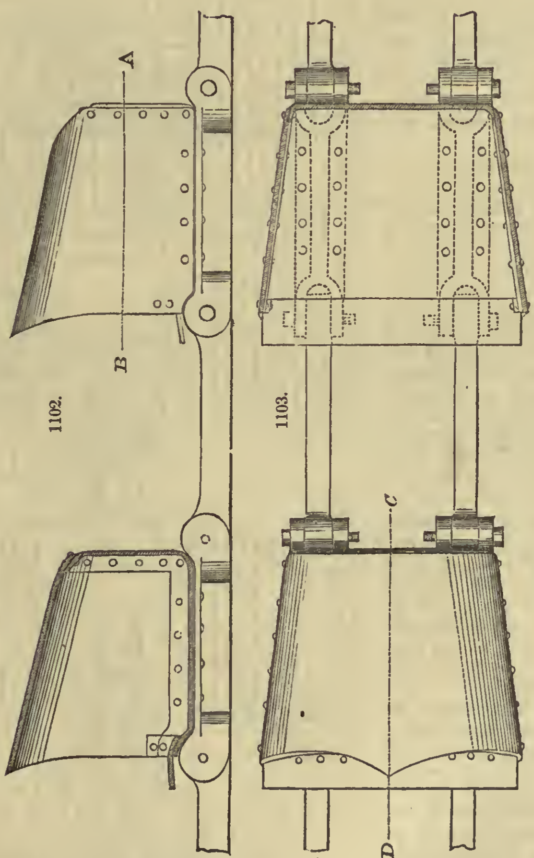


1100.

The wheels K and l are each two feet four inches diameter; the pinion m on the bottom of the shaft l is 10 inches diameter, and the wheel n four feet two inches. On the same shaft with the bevel-wheel n is fixed a spur-pinion g, of one foot seven inches diameter, which gives motion to the wheel o, of three feet three inches; the motion is communicated (when required) by means of the clutch $c\,c$, and, when the frame H is raised to a sufficient height, and placed at the requisite depth of water, farther motion of the barrel is prevented through disengaging the clutch by means of the lever W, and the barrel rendered stationary by the lever and friction-pulley $y\,y$. The clutch is two feet four inches diameter; the friction-pulley is three feet eight inches diameter, and its breadth of strap $3\frac{1}{2}$ inches. The length of the chain-barrel r is $4\frac{1}{2}$ feet, and its diameter two feet. The shaft t is $4\frac{3}{4}$ inches diameter, and the barrel-shaft $5\frac{1}{2}$ inches, each being of cast-iron.

The following is the number of teeth that each of the preceding named wheels contains, also the pitch and breadth upon the face:

Wheel or Pinion.	Number of Teeth.	Pitch.	Breadth.
Spur-pinion on crank-shaft C	49	$2\frac{1}{2}$ in.	$8\frac{1}{2}$ in.
Cog-wheel on end of laying-shaft D	112	$2\frac{1}{2}$	$8\frac{1}{2}$
Bevel-pinion, marked F	27	$3\frac{1}{8}$	8
Bevel-wheel " G	72	$3\frac{1}{2}$	8
Mitre-wheels " K and l	44	2	$4\frac{1}{2}$
Bevel-pinion " m	15	$2\frac{1}{8}$	$4\frac{1}{2}$
Bevel-wheel " n	75	$2\frac{1}{8}$	$4\frac{1}{2}$
Spur-pinion g on shaft with u	35	$2\frac{3}{8}$	5
Spur-wheel o on chain barrel-shaft	51	$2\frac{3}{8}$	5



1102.

1103.

The Bucket-Frame, Buckets, Links, &c.—The bucket-frame is of the best red pine, strongly trussed and strapped with iron, and in form and dimensions similar to the bucket-frame already described in the preceding machine; in length it is 55 feet 4 inches, and the number of buckets thirty-four, each bucket being $26\frac{1}{2}$ inches wide, 16 inches broad, 17 inches deep, and formed of the best plate-iron $\frac{3}{8}$ inch in thickness; on the back or sole plate p, of each bucket, and immediately beyond its formation, is an attached piece or continuation of the plate, so as to form a covering to the joints of the links, and so prevent any injurious effects from the constant liability of contact with the excavated materials; also

on the front of the buckets are fixed pieces of iron shod or edged with steel, for the purpose of increasing the strength of that portion of the bucket, and the better adapting of the same for coming in contact with hard materials; likewise that of being easily removed when required for repair.

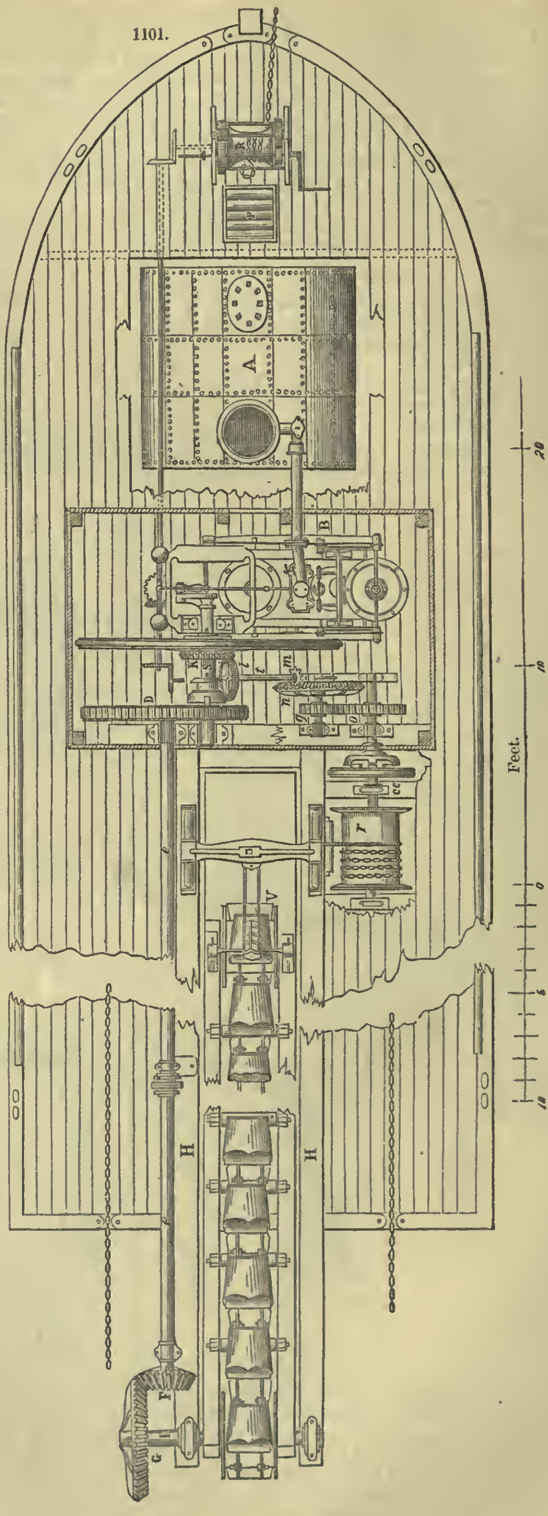
The links *x x x*, &c., that connect the buckets, are of wrought-iron, each link being 21 inches from centre to centre of joint; flanges are formed on the double links, as shown in the design, 2¼ by ⅞ths of an inch, and to which the buckets are fixed by ⅞ths of an inch rivets; the diameter of the joints is 3⅜ inches with ¼ inch projecting on each side, to increase the surface of bearing for the pins: all the joints and pins are cased with steel and properly hardened.

The rollers *r r r*, &c., are for the proper conducting of the buckets along the frame H, and are of cast-iron 8 inches in diameter, with axles or bearings of wrought-iron, 1½ inch diameter, and which revolve in cast-iron receptacles or bushes. The ends of the tumblers also revolve in cast-iron bushes, that metal being found more durable, for this purpose, than any hitherto tried.

It may not be out of place here, as being through the means of the action of the buckets and bucket-frame, to remark an idea or system given by a correspondent in the "Civil Engineer and Architect's Journal," which he calls *radius cutting*, in distinction to that of the common practice called *trench cutting*, and which no doubt in various instances must be of considerable advantage. In the ordinary method called *trench* cutting, the power applied to lead the machine ahead into the cutting, has also to resist the reaction of the buckets. Now, in *radius* cutting, the chain from the bow of the vessel is not wound up while it is cutting, but is only shortened at each return of the machine, and which causes a swinging motion of the vessel to take place, the machine being led laterally to the cutting by the side chains; and which are comparatively easy to work, as the reaction of the buckets is mostly against the *bow* or *radius* chain.

In respect to any inconvenience attending the use of these lateral chains, in a harbor or narrow navigation, it is no more than in the ordinary method, as corresponding chains are then required to keep the machine in line, and these are necessarily used on both sides at once; whereas, in the other system, these lateral chains are only tightened on one side, namely, that on which the machine may happen to be traversing; and where it is required to lower them, to allow vessels to pass, they only again require to be tightened up sufficiently to let the buckets fill.

1101.



It may be contended that, to cut or trench a bank in the proper current, will, by changing the currents and eddies, remove it by a natural process; but, as this is a point so difficult to hit upon, it is generally allowed that, to get large stones and rocks taken up, and to cut the surface fair, is the surest way of reducing a bank, and of leaving it in the condition least liable to "slit up."

The difference of construction in the machine is trifling, so as to adapt it to the radius principle, being only the doing away with the flanges on the bottom tumbler, and substituting in their stead "snugs" on the tumbler between the chains or links, to prevent their getting off. But it must be borne in mind in the constructing of dredging-machines for whatever kind of cutting, that a proper means be effected for preserving the chains employed in taking the vessel ahead, when the power of the engine is applied; and the best method that I am at present aware of is that of "conical friction."

The excavated material from the dredging-machines is carried away by punts, or large rectangular boxes of plate-iron. In dimensions, they are each 32 feet in length, 14 in breadth, and 3 in depth; through the deck of which is an opening 27 feet 8 inches by 10 feet 4, and around this opening is a cooming 10 inches in height, as a prevention to the stuff getting over upon the deck; each punt carries on an average 20 to 22 tons, and a small steam-tug of 70-horse power takes from 18 to 20 loaded punts at one time.

DREDGING AND RAISING MACHINE, by J. Hart, of Middletown, Connecticut.

Fig. 1104 is a horizontal plan of the mud dredging-machine.

Fig. 1105 is a vertical section.

A is a large flat vessel for receiving the boilers, fuel, engine, and principal parts of the machinery.

B is a small vessel for stores, &c., strongly connected to the larger one with the vibrating ways c for the buckets, strongly hung between the two vessels in a gallows-frame.

A is a crank, by which the power is to work the whole machinery, fixed on one end of the shaft b, which is strongly mounted in framing c.

On the shaft b is the fly-wheel e, and between that and opposite bearing is the clutch f, sliding on the shaft b, into or out of the clutch part of the driving pinion g, which geers into the larger tooth-wheel h mounted on that end of the bucket-shaft i; on this the chain-wheels $k\,k$ are fitted, each wheel made with four shifting-studs to lock into the long links of the bucket-chain. This chain is made so that each flat link has a curve to fit the wheels $k\,k$.

The edge link has a strong iron brace l^2 put in given lengths.

A connecting link is inserted, made with an open side turned up to receive a doubled-eyed collar.

In this mode of making a chain in sections, and using only four spurs or teeth, a chain can be worn one inch at each end, and not ride or turn on the teeth or spurs; each end of the links is lined with steel.

When worn or broken a section can be taken out to be repaired and replaced by another.

The chain-wheel $k\,k$ is a skeleton cast wheel to receive a shifting sectional stud or spur, with bolts to hold them in, which takes the strain off the chain, and allows them to be taken out and replaced by others when worn.

The friction rollers and water chain-wheel run on sleeves.

The raising and lowering of the buckets is effected by the slings and yoke in i, Fig. 1105, and chain h^1, which goes over the sheeve o, mounted on the double davit p, thence under the chain-wheel g to a sheeve at the head of the gallows-frame, and having at its inner end a counter-weight.

The chain-wheel g, fitted with a groove and studs to match the chain h^1, is mounted on a shaft fitted in bearings, and having the tooth-wheel w on one end, where it geers into the pinion x, which is fitted to a shaft mounted on bearings, and carrying on it the raising or lowering wheel E; this is made so that it serves as a hand-wheel by the spokes y^1, and as a drum by the flanged rim x^1, and through it the ways are regulated by the directing workman, who stands on the deck.

Immediately over the fly-wheel e, Fig. 1104, a frame i, Fig. 1105, is laid, to receive the bearing of the shaft t^1 on one part, forming a winch k^1, Fig. 1104.

At the other end, the drum s^1 is mounted, and over this is placed the belt, so that it hangs loosely around and below the fly-wheel e, and is kept from contact with it by the small rollers $q^1\,q^2$, mounted below the drum s^1, when not required in use in the pit. Formed by the frame which carries the drum s^1, are the two tightening drums $p^1\,p^2$ shown in Fig. 1104, as set over the fly-wheel e; these are hung in the swing-frames $o^1\,o^2$.

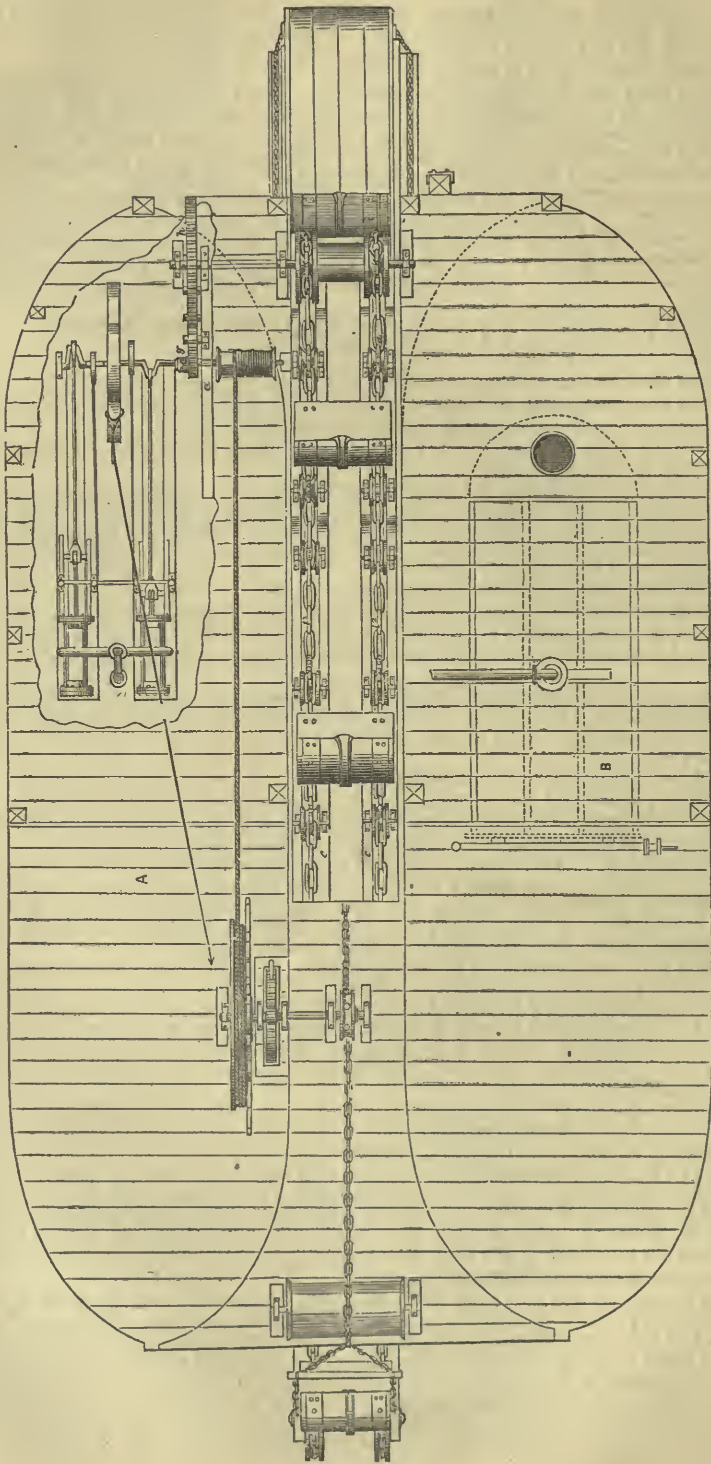
The upper part of each of these frames terminates in arms $u^2\,u^3$, and at one end of the frame u^1 is the vertical davit and sheeve m^2; a rope l^1 goes from the arm u^2 round the sheeve m^2 and returns and fastens to the arm u^3, and thence leads to the frame over the deck w^1.

The winch k^1, Fig. 1104, receives one end of rope i^1, the other end of the rope being attached to the drum x^1 on the wheel E; and the tooth-wheel is fitted with a pawl h^1 to retain it in its place as wanted. This part of the apparatus is to be used as follows: when the buckets are to be lowered, the attending laborer lifts the pawl h^1 back and turns the ways-wheel E in the direction of the arrow 1 by the spokes y^1; this lowers the ways, and at the same time is winding the rope i^1 off the windlass k^1: the belt r being slack does not hinder the operation of lowering.

When the bucket and ways are to be raised, the attendant laborer leaves the wheel E and simply hauls on the rope l^1, which pulls the arms u^2 and u^3 outwards, and forces the drums $p^1\,p^2$ inwards against the belt below in contact with the rim of the fly-wheel e, whose motion round drives the raising-wheel E round in the direction of k^1, raising the ways and buckets easily and rapidly.

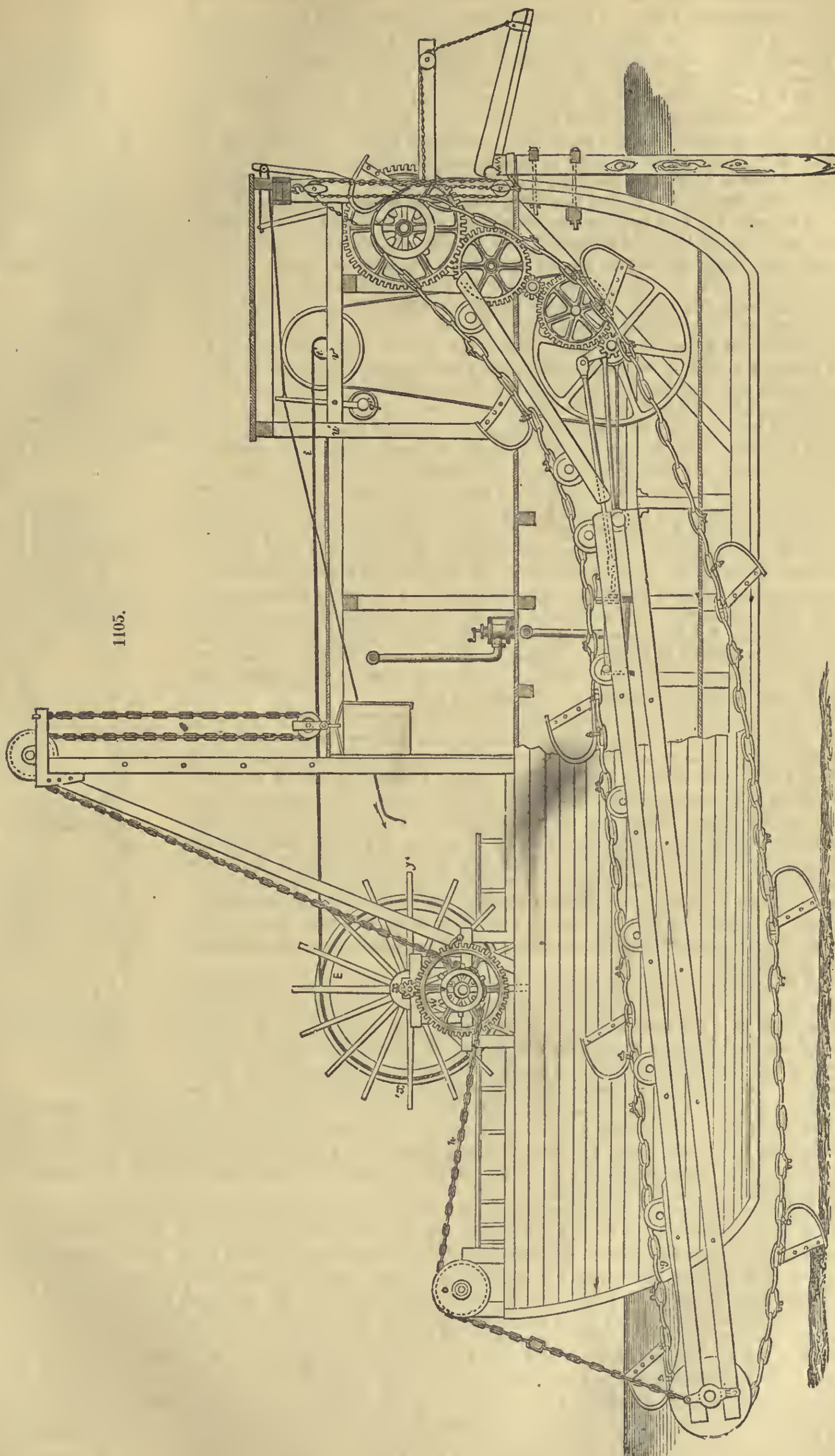
Near the machinery in the smaller vessel B, projecting over the end, is a frame forming a slide, carrying the anchor-post. This is raised by a chain running through sheeves; then by taking a turn around the end of the bucket-shaft i, the end forms a windlass barrel for that purpose. This anchor-post holds one end of the machine; the other end is moved the width of the buckets at a time by a pawl, windlass, and lines.

1104.

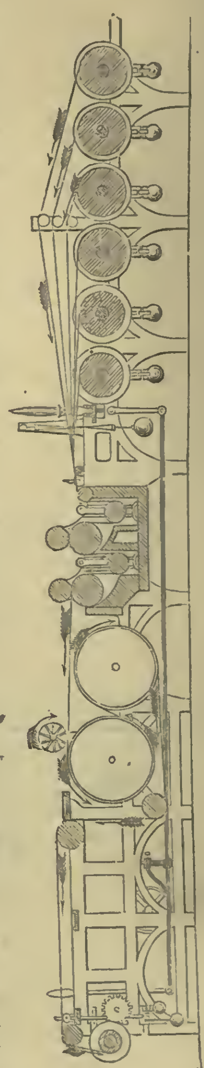


Scale.—25 feet=3 inches.

1105.



SCALE.—25 feet=3 inches.



DRESSING MACHINE. Fig. 1108 is a section of an English Dressing Machine as constructed by Hornby and Kenworthy. Six beams are placed in bearings so that they will revolve, having retaining weights upon their pivots; the six threads of yarn are then passed through an ordinary comb-bar and thus divided equally until passed through the healds, which in this machine are situated at the left end, for the purpose of effecting the cross-shed, and thereby taking the "lease," previously to the yarns being submitted to the sizing process. The lease now being taken, and the cross-band or threads being introduced for the purpose of "looming," or drawing in of the weaver's beam, the threads of yarn are passed over a comb-bar, formed by a row of teeth or pins, for the purpose of laying the threads in parallel breadths, side by side, and forming each division of threads (of any required number) into distinct bands (of any desired width), each thread being laid parallel, side by side, and thus in lateral contact, the comb-bar being allowed to vibrate or oscillate freely as the threads proceed. The bands are now passed over a conducting roller, and immersed into the trough containing the sizing material, which is here kept in a heated state by steam pipes, and thus boiled into the warp threads as they are passed through it and under the adjustable tension roller. The threads are then passed forward through a pair of squeezing-rollers, and again similarly immersed in the trough containing the size to finish the yarn, from whence they are passed around the drying cylinders, also heated by steam, and now assume the form of tapes, (the sizing material, by its adhesive properties, causing the threads to adhere slightly together). A circular revolving brush is placed above the threads as they proceed over the drying cylinders, for the purpose of dressing or laying the fibres. They now proceed in a sized, dried, and finished state, being conducted by two rollers through a similar comb-bar, but of much finer pitch, and by passing through which the bands of threads are passed edgewise and again similarly divided by the oscillating or vibratory action of the comb-bar, and laid over the tension roller at the right hand end of the machine in a proper state to be received and wound upon the warp beam ready for the operation of drawing in.

Fig. 1109 represents a side view of the dressing-machines used at Lowell and its vicinity. A A is the centre-frame, B B B are the section frames, containing the section-beams H H H H. The ends of the section-beams are of cast-iron, with a square groove for receiving a friction-strap, and a weight represented at *v v v v*. The sizing-rollers are represented at *y y y y*.

The yarn as it leaves the section-beams, passes through a raddle of small pieces of hard wood, *u u u u*, through between the sizing-rollers,—through a brass wire reed at *o o o o*,—through a copper-plate supported by *b b*,—through another brass wire reed at *d d*,—and under the measuring rollers N N,—at which place the yarn from the four beams on each section are brought all into one horizontal plane. From the rollers N N, the two sections of dressed yarn pass up through heddles at *k*, called the lease-harness, and are wound on to the centre-beam *a*. The lease-harness may be shifted to either side of the frame by means of a screw at *k*, and only one section of the yarn goes through heddle-eyes in the lease-harness; so that when a full beam is to be removed, a lease-rod is introduced between the two sections of yarn above the harness; then, by drawing the harness to one side, another lease is formed, into which a rod is introduced.

F are the fast and loose belt-pulleys, driven by a belt from the room below; *n n* are two cones, that to the right being driven from the one to the left, by the cross-belt R. On the axis of the cone to the right hand, there is a small bevel-wheel working into another on the bottom of the upright shaft *r r*. On the top of the upright shaft there is a small bevel-wheel working into the wheel *c*; and on the axis of the wheel *c*, there is a small spur-geer, not seen in the engraving, working into the wheel E, on the centre-beam *a*. Motion being thus given to the cone on the left hand, (by the belt-pulley F which is fastened on the same shaft,) it is next communicated by the belt R to that on the right, and from it to the beam on the top, containing the dressed yarn; hence the speed of the centre-beam *a*, on the top of the centre-frame, may be increased or decreased, by shifting the belt R, on the cones *n n*.

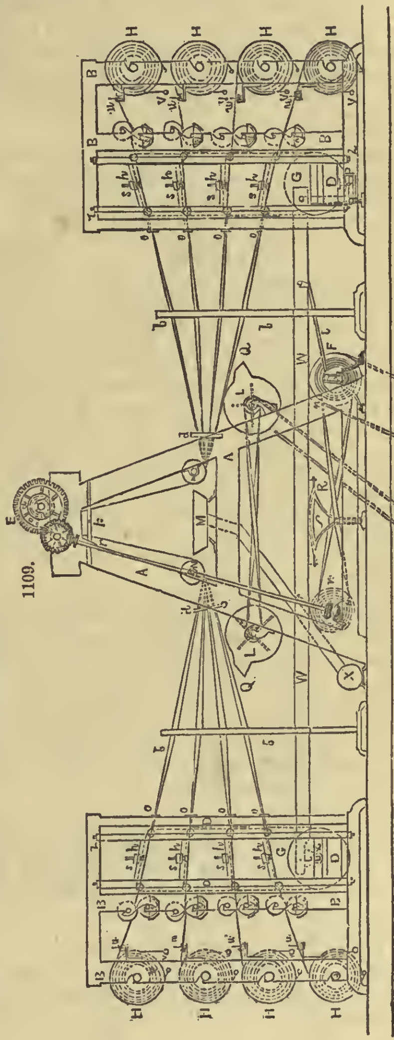
The brush-motion is next to be considered. D D D are the brush-racks, or brush-frames; they are not fastened to the section-beam frames B B B, but are fitted so as to move up and down, short spears *z z* being fixed to the top and bottom of each side of the brush-frames, which slide into the eyes of studs, and serve to keep them in their proper position, as well as to let them move freely up and down: *s s s s* are small blocks of cast-iron, which are fitted to slide freely on the polished steel-rods *h h h h*; the dotted lines represent straps or belts passing over small pulleys on each side, and descending down to the large wooden pulleys G G, to the surface of which the belts are fastened: the blocks *s s s s* are fastened to the belts by a small nut and screw on the under side, whilst the brushes rest on the blocks above. The feathers represented on the blocks at *s s s s*, fit into slits in the ends of the brushes. W W represent two beams of wood, (one at each side of the machine,) about four inches broad, and three inches thick, called sweeps; these are supported in the centre at *f*, and at the end towards the left hand, they are attached to the lever P P, the under point of which supports the whole brush-frame the other end of the sweeps being attached to the block *i*, towards the right hand: the block *i* is a

Engd by W G Jackman

CHAS HUTTON, L.L.D. F.R.S.

N Y D Appleton &

projection from a shaft, extending across the machine at each section, the axis of which is seen at x, and the pulleys G G are fastened on each end of this shaft. By carefully examining the engraving of the various parts of the machine, the reciprocating motion of the brushes, together with the up and down motion of the brush-frames, will now be easily understood. The lever J is connected with a sliding-crank on the axis of the cone n, towards the left hand; consequently, the revolving of the crank moves the sweeps alternately, from section to section; and the end of the sweeps to the right hand, being attached to the block i by a strap of belt leather, the alternate motion of the sweeps moves the shaft x, and with it the pulleys G G, about one-fourth of a revolution each way: this reciprocating motion of the pulleys, draws each end of the straps represented by the dotted lines, and thereby produces the necessary reciprocating movements of the brushes upon the yarn; while, at the same time, the other end of the sweeps towards the left hand, by means of the lever P P, raises the brush-frame, and with it the brushes, up and down at every alternate stroke. Thus, when the brushes are at $h\ h\ h\ h$, the frame is down, and they are then in a proper position for moving along the surface of the yarn, (which has just been coated with size, in passing through between the sizing-rollers,) and having made one full stroke, they are then at the opposite side of the frame, which is immediately raised by the lever P P, connected with the sweeps; and in raising the frame, the brushes are lifted out of the yarn, until they return to their former position at $h\ h\ h\ h$. The whole movements of the machine commence at the cone n, towards the left hand. From it, motion is communicated by the belt R, to the opposite cone, and from it, to the centre-beam a at the top; and from it, (the cone n,) motion is also communicated by the sliding-crank, and the connecting-lever J, to the sweeps W W, of which there are two, and the one end of each moves the brushes alternately from side to side, whilst the other end produces the up and down motion of the brush-frame. The whole machine is extremely simple, and all its different movements so contrived, that they can easily be adjusted so as to operate with the most perfect accuracy.



1109.

Scale.—4 feet=1 inch.

L L represent the fanners enclosed in wooden boxes, open only at the centres for admitting a current of air, and at the mouths Q Q, for throwing it out: by this method of confining the air, it rushes out with much greater force, and the mouths Q Q are made so as to direct it right up amongst the dressed yarn. The fanners here represented have four wings each, but some have only two or three: that to the left hand, is driven by a belt from the room below, and from it, a cross-belt communicates motion to the one on the right. X is a hot-air pipe, with a branch extending up to the hot-air box M, placed between the two rollers N N. The cover of this box extends till within one half-inch of each side, which leaves a small opening for the escape of the air, which issues out at each side upon the yarn, and being entirely hot air, it has a peculiar effect in absorbing any remaining moisture upon the yarn, before it is wound on to the centre-beam a, on the top. Instead of the hot-air box M, some dressing-frames have a centre fanner, similar to those used about Manchester.

The sizing-rollers $y\ y\ y\ y$, are generally made of soapstone, with an iron axis; the under roller only is covered with cloth: one of these rollers, when finished, costs about eight dollars.

The two sections of these dressing-machines may be extended out as far as may be thought necessary. In order to diminish the size of the plate, the distance from the centre of the section-beams to the centre of the frame, is represented as only 9½ feet; some, however, extend to 17 or 18 feet. As the greater the distance from the sizing-rollers to the centre-beam containing the dressed yarn, more time will be gained for drying; but when the section-beams are stretched out too far, the yarn is more liable to break with the drag of the centre-beam.

On one end of the axis of the measuring-rollers N N, there is a screw or worm working into geers, connected with an index which points out the number of yards of dressed yarn on the centre-beam; every 33 yards is marked with paint, which allows 30 yards of cloth to each piece, the 3 yards (equal to 10 per cent.) being allowed for shrinkage in the weaving, &c.

The measuring-rollers, in general, are common wooden cylinders, about eight inches in diameter some are revolving steam-cylinders, which, when properly packed at the journals so as to prevent the steam from escaping, has the best effect of any thing that has yet been tried for drying the yarn speedily.

The average produce of these machines is very variable. In some factories, their average produce will be about 14 pieces per day to suit a 9^{00} reed; yarn, Nos. 14's to 18's. In other factories, on the same kind of work, these machines will dress 20, in others 30, 40, 50, and 60 pieces per day. Some of those fitted up with revolving steam-cylinders, are said to produce even 70 pieces on the same kind of work, viz., coarse 9^{00s}, yarn No. 14's. One great cause of this difference in the quantity produced from the dressing-machines, arises from the different temperatures in the apartments where they are in operation, as well as from the mode of applying the heat to the dressed yarn. In some factories the dressing-machines are in the same room with the looms, where the temperature seldom exceeds 75°. Those mounted with steam-cylinders, in place of wooden measuring-rollers, generally produce the greatest quantity of work; next to these, are those with the hot-air pipes; and next to the latter, are those with three fanners, that is, one at each side, and one in the centre. Those with only two fanners, produce the least quantity of work.

The size used for dressing is generally made of potato starch for all coarse work; and of flour for the finer goods, or such as are intended for printing. The mode of preparing the starch for size requires particular attention; and although different places may have different methods, the two following have been found to suit the purpose remarkably well.

1. *Method of making Size from Potato Starch for coarse Goods.*—2½ gallons of yeast, and 2 quarts of vinegar, to be well mixed with about 9 gallons of water, which has been previously heated to 120°, or as hot as the hand will bear to work in it. To these are added 125 lbs. of potato starch. The whole is then allowed to stand in a warm place about 10 or 12 days, or until it is perfectly fermented; then 3¼ lbs. of common clean tallow is dissolved in 75 gallons of water, heated to 160°, to which are added 75 lbs. of the fermented starch. The whole is well stirred until all the ingredients are perfectly incorporated. The size is then to be used immediately before, or after it is perfectly cooled down. To the above some add about 2½ lbs. of the sulphate of copper, to prevent mould.

The above makes a very superior size. It is smooth, clean, and entirely free from any offensive smell; and although about the same price as flour, it is found to answer the purpose much better for coarse goods; very little of it adheres to the yarn, yet quite enough to make it weave well.

2. *Method of making Size from Flour for the finer Goods.*—300 lbs. of flour mixed in 45 gallons of water, and allowed to stand for four or five days at blood-heat, until it is perfectly fermented; this is called yeast. To the above are added about 140 gallons of water heated to 180°. The whole is then boiled by steam from 30 to 45 minutes. At first it boils thick, but by continued boiling it becomes thin in the middle, when it is considered done; after which it should stand over one week, and be reduced with cold water when used.

The following mode of making Size from Flour is practised in Glasgow for various kinds of Goods:—One barrel of flour is soaked in water which had been previously heated a little over 120°, and allowed to stand in this state about a week, or until it ferment thoroughly. It is then mixed with about 110 gallons of water in a copper boiler, with a cast-iron casing; and by introducing steam into the boiler, as well as into the vacant space between the casing and the boiler, it is gradually heated until it boils; after which the steam may be admitted at any pressure, and the boiling process continued about an hour; during which an agitator, driven by the engine, moves round with a slow motion, until all the concretions or lumps are completely dissolved, when a wooden roller being dipped into it, if the small portion which adheres to the roller has a thick, smooth, glutinous appearance, it is then ready to be emptied out into narrow deep vessels to cool, in which it is allowed to stand for three or four days before using it.

Besides the kind of dressing-frame just described, there is another made at Providence, Rhode Island, and generally used throughout that part of the country, known by the name of Pitcher and Gay's dressing-frame. The principal difference between it and the one already described, is, that the former has four pairs of sizing-rollers on each section, while the latter has only two; that is, the yarn from the two upper beams passes through between one pair of sizing-rollers, and that from the two under beams through another pair.

DRESSING MILLSTONES, *Machine for.* We have had occasion to notice, in our descriptions of corn-grinding machinery, the frequency with which it is found necessary to renew the grinding surfaces of the stones, and the great care and accuracy to be observed in thus preparing them for their work. The operation consists in roughening the surface of the stone, when worn smooth, by cutting delicate and very regular furrows between each of the radial grooves and parallel to them, and depressing the latter to a degree corresponding with the amount of the grinding surface removed. Skilful and experienced workmen are employed for this service, which they accomplish by the help of hammers, provided with chisel-edges, of well-tempered cast-steel.

Simple as this operation may appear, the attempts hitherto made to perform it entirely by machinery have proved abortive; and we need not be surprised at this, when we consider the various degrees of hardness and compactness presented by different parts of the same stone, as well as the differences in the nature of the grain which is to come under its action. To accommodate itself efficiently to such circumstances, a machine would almost require of itself to possess intelligence. But although it may safely be pronounced impossible to dispense with manual labor in this process, it may be accomplished with much greater dispatch and precision by the use of the simple machine, or more properly *instrument*, which we have represented in Figs. 1110 to 1121.

This instrument serves simply to guide the hand of the workman, and to restrict the cutting edge of the hammer into a perfectly parallel and rectilinear course; the force and number of the blows being left entirely to the discretion of the workman. By a simple contrivance, it is also made available for

regulating with the greatest nicety the degree of fineness, or in other words, the distance between the furrows, of the grinding surface of the stones, according to the nature of the work on which they are to be employed.

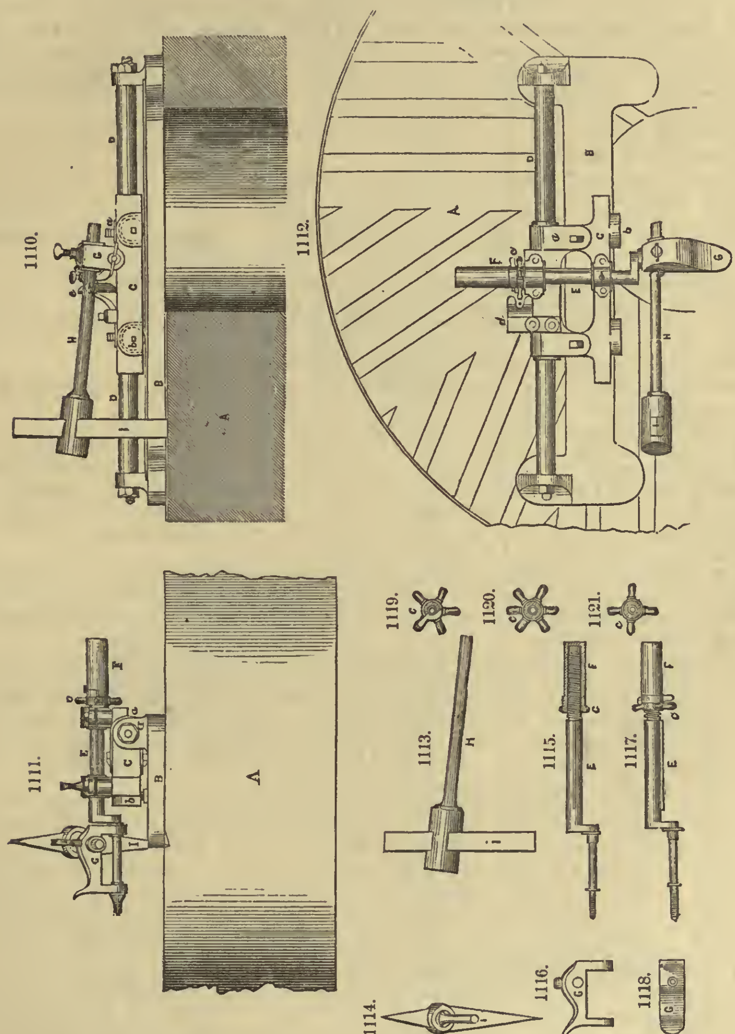
Fig. 1110 is a side elevation; Fig. 1111 an end view; and Fig. 1112 a plan of the entire machine.

Figs. 1113 and 1114 are views of the hammers and cutting tool detached from the machine.

Figs. 1115 and 1117, a sectional view and corresponding plan of the axis E, and its screw and nut.

Figs. 1116 and 1118, detached views of the saddle or guide for the hammer.

Figs. 1119, 1120, and 1121, represent the various handles used for varying the distance between the cuts the first having five, the second six, and the third four rays or points.



Scale.—1 foot=1 inch.

The base of this machine, which simply rests, without being fixed, upon the dressed surface of the millstone A, consists of a narrow cast-iron plate B, also dressed on its under surface, and of sufficient weight to retain it in the position in which it is set, without at the same time impairing its portable character. On this sole-plate a carriage C is fitted to traverse longitudinally; being supported at one side by a smooth cylindrical rod D, bolted to the sole-plate, and passing through the brass-mounted sockets *a a;* while, at the other side, it is provided with small friction-rollers *b b*, resting on the sole-plate. At right angles to the direction of this motion, an axis E is fitted to slide on bearings cast upon the carriage C; the outer extremity of this axis is formed into a screw, worked by the nut F; and the opposite end, which is cranked, carries the saddle G, into which the hammer-handle H is inserted, and which guides the action of the cutting-tool. The nut F is elongated so as entirely to enclose the screw and protect it from injury; it is also provided with a set of star-handles *c c′ c″*, either of which may be affixed to it according to the degree of fineness which it is required to give to the stone. The first has

six rays, and gives the greatest degree of fineness, the distance between the cuts being only one-sixth of the pitch of the screw; the others, having fewer rays, give correspondingly increased roughness to the stone. A species of index *d*, fixed to the carriage, serves to regulate the exact amount of motion given to the nut. The cranked form given to the axis E is for the purpose of adapting the machine to the length of the cutting-tool I. The manner in which this adjustment is accomplished will be obvious from inspection of the drawings.

Action of the Machine.—This instrument being laid upon the surface of the stone, with the edge of its sole-plate exactly parallel to one of the great radial grooves, the carriage C is pushed by the hand of the workman towards the circumference of the stone, until the cutting-tool I reaches it.

He then begins his strokes, varying the number and intensity of them according to the hardness of the stone, and the depth he wishes to give to the furrows; and drawing the carriage C slowly with his left hand towards the centre of the stone, until the whole grinding surface is traversed by the tool. The hammer is then set into the position for making the next adjacent furrow, by turning the handle *c* through another of its divisions; the carriage is again slid towards the circumference, and the operation continued as before. Thus the requisite straightness, regularity, and parallelism of the grooves is ensured and the operation of dressing materially facilitated.

A, the millstone to be re-cut.

B, the base-plate of the machine.

C, the carriage or support of the working parts of the machine.

a a, straps of iron binding the carriage to the cylindrical rod D.

b b, friction-rollers between the carriage and sole-plate.

D D, a cylindrical horizontal rod, turned smooth, for guiding the carriage C into a rectilinear movement.

E, an axis sliding transversely in bearings, and carrying the guide for the hammer.

F, nut by which the position and motions of the axis E are determined.

c c c, star-handles for regulating the fineness of the cut; the first having six, the second five, and the third four rays.

d, an index for regulating the exact amount of travel given to the nut F.

G, a cast-iron saddle fitting to the cranked end of the axis E, and serving as a guide to the hammer.

H, the wooden handle of the hammer.

I, the chisel or cutting-tool inserted into the head of the hammer.

DRILLING-MACHINE, *by Messrs. Joseph Whitworth & Co., Manchester.* This machine answers all the purposes for which tools of this kind are intended, and is made self-acting in all its motions.

Fig. 1122 is a vertical section in the plane of the axis of the driving-cone and work-table.

Fig. 1123 is a front view of the machine, agreeing in its letters of reference with Fig. 1122.

The other figures are drawings of the parts of the machine, which are necessary to a full description of its construction and motions, and have the same letters of reference.

A A A A indicate the form of the cast-iron framing of the machine, upon which all the working parts are carried, as also the work-table and its motions. This framing is formed of a single casting, and is fixed by three strong bolts upon the sole-plate T T, intended to rest solidly, and without any fastening, upon the floor of the workshop.

On the upper portion of the main frame a strong bracket is cast, which serves to carry the outer ends of the cone-spindle *b*, and back-speed spindle of the machine. Upon the spindle *b* is the driving-cone B of three speeds, the spur-wheel C, and the bevel-pinion D. The speed-cone B is loose upon the shaft, and only communicates motion to it by means of the spur-wheel C, which is keyed upon the spindle, and to which the cone *can be attached* by a stud-pin and nut at *c*. This wheel geers with the pinion E, on the same spindle which carries the wheel M; this in turn geers with the pinion N, which is fast upon the end of the cone B, but runs loose upon the cone-spindle *b*.

This arrangement is in every respect the same as the ordinary back-speed of a lathe, and serves the same purpose. Supposing the back-speed removed, the cone being driven by its belt causes the spindle *b* to revolve, in consequence of its attachment to the fast-wheel C, and at the same time gives motion directly to the bevel-pinion D on the end of the spindle. This again geers with the bevel-wheel F, on the drill-spindle G G, which is free to slide vertically in the eye of the wheel, while at the same time it is prevented from revolving in it by a sunk feather. By this means three different degrees of quick speed may be communicated to the drill. But let the back-speed be in geer, as represented in the drawing, Fig. 1122, and let the stud-pin *c* be removed, and the cone thereby loosened from its attachment with the wheel C, the motion being communicated to it will not drive the shaft *b*, directly as before, but the pinion N being fast upon it will give motion to the wheel M, upon the same spindle with the pinion E. This last will therefore make the same number of revolutions as M, but being less in diameter will convey a proportionally less velocity to the wheel C, with which it geers, and which it consequently drives with a speed diminished in the ratio of the geering pairs. Now the wheel C being fast on the shaft *b*, conveys through it to the bevel-pinion D the same diminished speed, and this again to the drill-spindle G G. This reduced speed may, of course, be varied as before, by placing the belt on one pulley or other of the speed cone.

Behind the pinion E there is a recess cast in the framing, to allow it to enter when the back-speed wheels are to be thrown out of geer; and it may be remarked that this speed-geer is only required to be in action when the machine is employed in boring holes of upwards of an inch and a half in diameter.

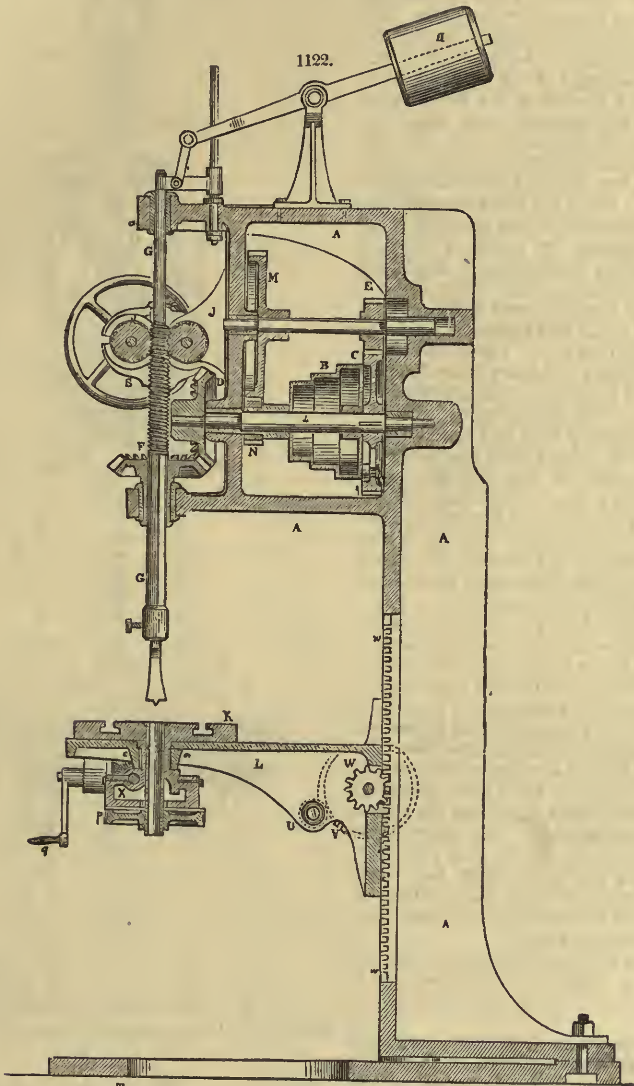
The wheel F is cast with a long hollow boss, which is turned and fitted into a brass collar in the lower branch of the carrying-bracket, as seen in Fig. 1122. This collar is kept in its place by a cover bolted over it, as shown in Fig. 1123.

As already observed, the drill-spindle passes through the wheel F, which thus serves as its lower guide. The upper end of the spindle is at the same time guided in a collar similarly fitted into the

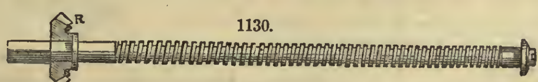
upper branch of the bracket at *a*, and is thus guided vertically in ascending and descending. (In the drawings it is shown at the lowest limit of its travel.)

To the top of the drill-spindle is attached the back-weight H by a jointed lever and guide link, which embraces the top of the spindle and moves upon a vertical guide-rod, kept firm in its place by having its lower end held by a screw-nut, in a socket cast in the bracket, in the manner of a bolt, a ruff forged upon the lower end of the rod answering to the head of the bolt.

1122.



1130.



SCALE.—12 feet=7 inches.

The drill-spindle is itself screwed towards the middle of its length; it is there embraced by two screw-wheels J J between which it turns, and which serve the purpose of a nut to feed down the spindle in the operation of drilling, by an arrangement which will presently be described.

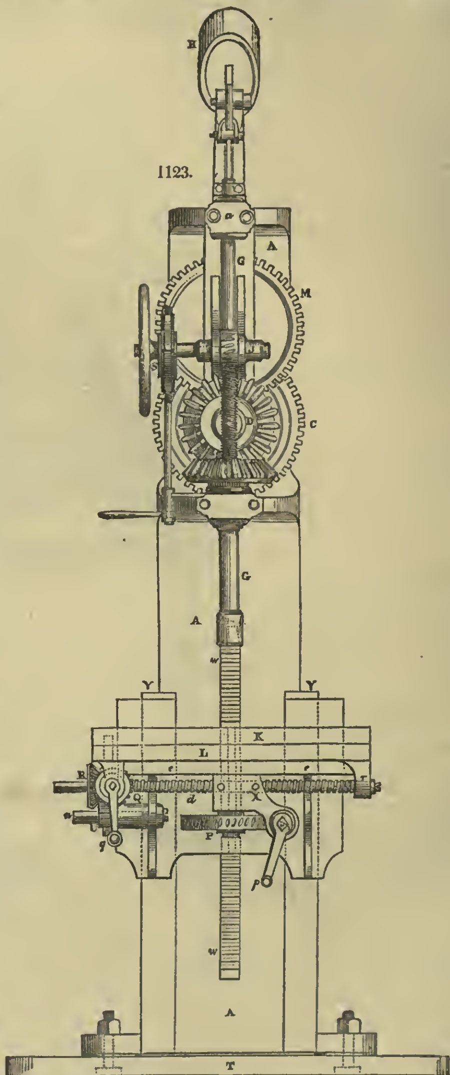
K, is the table upon which the article to be bored rests, and to which it can be firmly held down and adjusted by T-headed bolts and glands in the usual way, when thought necessary. The table, it will be observed, is recessed and grooved to receive and retain the T-heads of the holding bolts, as fully shown in the horizontal section, Fig. 1124, and the side view, Fig. 1125. When the article is much smaller in area than the surface of the table, the fixing bolt-head can be entered at any convenient point

of the surface by the recesses k k, and slid forward until it passes below the projecting ledges of the recess, where it is retained.

The common mode of running two sets of inverted dovetail-grooves at right angles to each other lengthwise and across the table, seems, however, preferable to this mode of partially recessing the surface.

The table is itself supported upon the sole of the large carriage-bracket L, which is strengthened by two strong ribs cast on its under side. This bracket is attached to the framing A A by two pieces Y Y, which are bolted upon it and planed true to the angle of the inverted bevel edges of the broad face-rib of the main frame. These edges are also planed where they meet the oblique faces of the pieces Y Y. By this means a joint is formed which allows of a sliding motion vertically, but does not admit of any deviation laterally. When the slides become loose by wearing of their surfaces, the pieces Y Y admit of being tightened by means of pinching screws fitted against them through continuous snugs cast on the bracket. This arrangement is fully explained by Figs. 1124 and 1125.

1123.

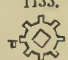


This bracket is raised and depressed by means of a hand-crank applied at u. Upon this spindle is fixed the spur-pinion U, (shown in combination by Figs. 1122 and 1123, and separately by Figs. 1132 and 1133.) This pinion geers with the spur-wheel V, (partially seen in Figs. 1122 and 1123,) on the same spindle with the pinion W, Fig. 1122, which geers in turn with the rack w set into the frame A A of the machine, so as to form an integral part of it. By turning the hand-crank on u, it is thus manifest that the motion will be transmitted to the bracket, which will either be raised or lowered according as the crank is turned in one direction or the other.

The table K has a double movement upon the sole of the carriage-bracket; one movement is circular and the other is in the direction of the length of the table. The circular movement is effected by means of the hand-crank p upon the spindle y, carried in bearings formed on the box X, which thus serves as a centre of rotation. On the spindle y is formed a worm, which, geering with the worm-wheel P on a stud projecting downwards from the table K, conveys the motion of the handle p to the table. This arrangement is well shown separately by the plan Fig. 1127, and the elevation Fig. 1126. This last corresponds to the view given in Fig. 1123. Opposite views of it are also given in Figs. 1122 and 1125, the last on an enlarged scale.

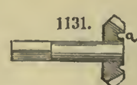
It will be observed that the stud on which the worm-wheel P is fixed, is cast hollow, and is fitted into the table K by a key at o, shown in Fig. 1124.

1133.



1132.

1131.

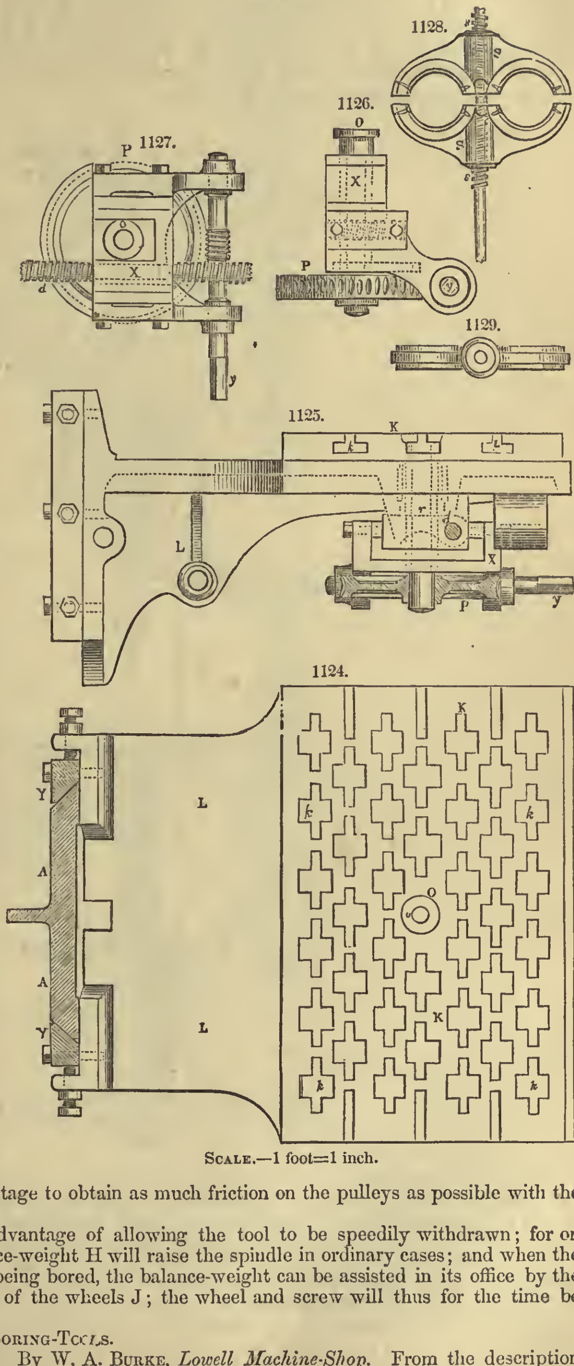


SCALE.—12 feet=7 inches.

The lateral movement of the table is effected by a different arrangement. A recess in the form of a parallelogram is cast in the sole of the carriage-bracket L, with projecting ribs $e\,e$ on its under side to serve the double purpose of giving strength to the sole-plate and of forming guides against which the cover of the travelling-box X may slide, the surfaces in contact being planed true for that purpose. The motion is communicated by means of the handle q, (Figs. 1122 and 1123,) upon the spindle which carries the bevel-wheel Q, (seen in Fig. 1123, and partially in Fig. 1122; also separately in Fig. 1131;) this spindle has its bearings attached to the bracket L, and its wheel-geers with the equal wheel R upon the end of the screwed spindle d, which has its bearings r also attached to the sole-plate of the carriage-bracket, and works in a long nut or internal screw formed in the cover of the travelling-box X, (see Fig. 1123 for the general arrangement, also Figs. 1125, 1127, and 1130.) By turning the handle q it is thus clear that the piece which serves the purpose of a nut on the screw d, will be carried along in the direction of the length of the screw; but the nut being attached to the table K, the whole will be moved simultaneously in that direction.

By means of these two motions any point of the table K can be brought under the axis of the drill and by means of the vertical motion it can be placed at any convenient height.

The feed of the tool during the operation of boring is obtained, as before stated, by means of the two screw-wheels J J, by an arrangement of parts which forms the chief novelty of this machine. On the axes of these wheels are placed two pulleys, the circumferences of which are embraced by the friction collars S S, (shown in combination in Figs. 1122 and 1123, and separately by Figs. 1128 and 1129.) The bearings of the axis being attached to the framing A A of the machine, it is obvious that the machine being in motion, if the pulleys be prevented from revolving, the wheels J J will likewise remain at rest; but the screwed part of the drill-spindle revolving between them, they will act as a stationary nut, and cause the spindle to descend through a space equal to one thread of its screw during every revolution. Again, suppose the pulleys and wheels free, the screw of the spindle, instead of descending will simply cause the wheels J J to revolve on their axes through a space equal to one tooth during every revolution of the screw. Now, between these extremes any amount of feed or downward motion of the drill-spindle may be obtained by simply retarding the motion of the wheels, by means of the friction-collars S S, which embrace the small pulleys on their axes; for the friction of the collars being less than to prevent entirely the motion of the wheels, and, at the same time, greater than to allow a tooth to pass during a revolution of the spindle, a downward motion of the spindle must thus be produced equal to the retardation of the pulleys produced by the friction-collars. Thus, any degree of feed can be produced at pleasure by the contrivance of the friction-collars shown separately in Figs. 1128 and 1129. These collars are formed in two halves S and S, with bosses joining the segments, pair and pair; these bosses are reverse screwed internally, the thread of the one to the right, and that of the other to the left; and being placed on a rod *s s* correspondingly screwed right and left, they are made to approach or recede according as this rod is turned to the right or left, and to embrace more or less closely the surface of the pulleys upon which they are placed. This screwed rod is prolonged, and has a handle placed on its under end, by which the required degree of friction can be adjusted at pleasure, (see Fig. 1123.) The friction-collars are lined with copper, for the purpose of increasing the friction; for it is manifestly of advantage to obtain as much friction on the pulleys as possible with the least amount of pressure.



SCALE.—1 foot=1 inch.

This arrangement has also the advantage of allowing the tool to be speedily withdrawn; for on slacking the friction-collars the balance-weight H will raise the spindle in ordinary cases; and when the tool has a hold in the hole which is being bored, the balance-weight can be assisted in its office by the hand-wheel placed on the axis of one of the wheels J; the wheel and screw will thus for the time be converted into a pinion and rack.

DRILLING-MACHINES. See BORING-TOOLS.

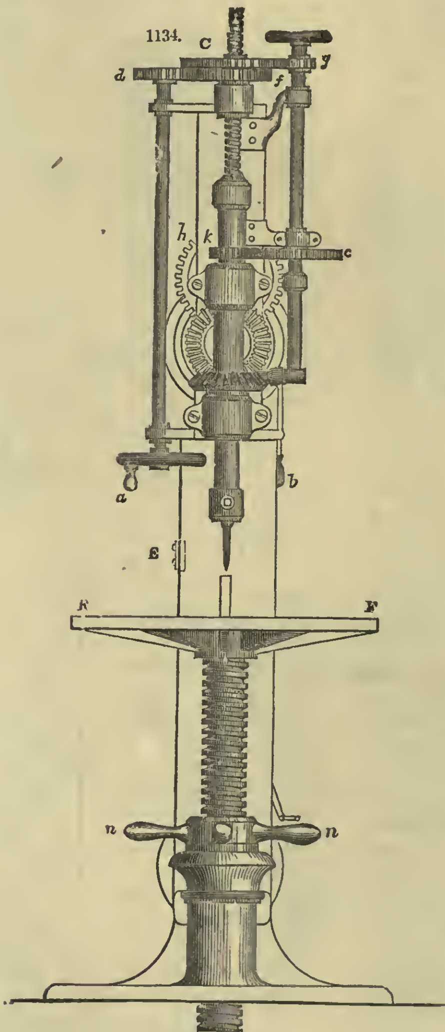
DRILLING-MACHINE, *Vertical*. By W. A. BURKE, *Lowell Machine-Shop*. From the description already given of Whitworth's drilling-machine, it is needless to enter minutely into a detailed descrip-

tion of this very complete machine. Fig. 1134 is a front view of the machine. Fig. 1135 is a side elevation in the plane of the axis of the driving-cone and work-table.

The frame of this machine is of iron, cast in one piece, having a broad base or sole-plate at the bottom, by which it can be properly fastened to a stone or other suitable foundation.

Fig. 1135. N is the loose and fast driving-pulleys. D, on the same shaft, is a set of cone-pulleys which communicate the power by a belt to a corresponding set of cone-pulleys. T, near the top of the frame *r r* and *h h*, are geers for decreasing the motion of the drill, similar to the back geering of turning-lathes. Upon the shaft which carries the cone-pulleys T is a bevel geer, which drives another bevel geer made fast on the spindle-tube B. This tube runs loose in gun-metal bearings, and carries round the steel spindle to which the drilling-tool A is attached, by means of a long splice in the spindle and a corresponding groove in the tube.

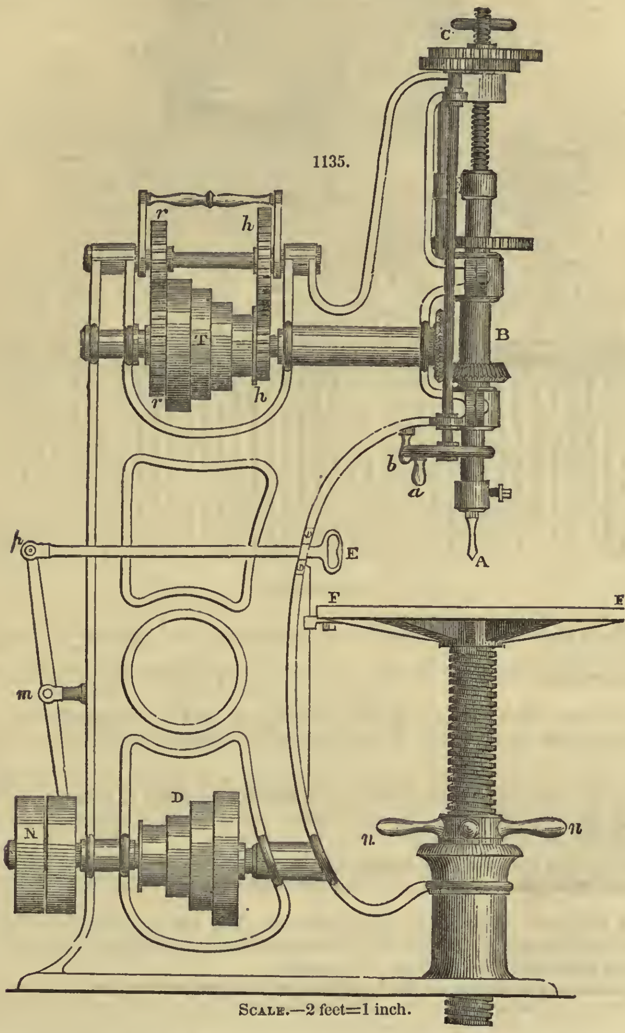
1134.



The machine is adapted to feed the drill down by hand, or it can be made self-acting. When feeding the drill by hand, by turning the hand-wheel *a*, Fig. 1134, motion is communicated through the geer *d* to the geer *f*, which is fastened to a revolving nut which moves the feeding-screw up or down as wanted. The screw is prevented from turning round by means of a coupling which connects the screw to the spindle, and slides on a parallel rod lying back of the screw. When the feeding is to be self-acting, the geer *k*, which is fastened to the tube B, drives the geer *c*, fastened on its shaft by a splice and groove. This shaft admits a motion upward sufficient to raise the geer *g* on its upper end from driving *c*. When the feeding is done by hand, this upward motion is produced by moving the handle *b*, which is on the end of a bell-crank lever jointed to the end of the shaft. By means of friction-collars each side of pinion-geer *g*, pressure to which is given by a small hand-wheel, the quantity of feed can be raised so as to suit the size of the hole to be drilled. The circular table F F on which the work to be

drilled is laid, is prevented from turning round by means of a stop which slides on a rib cast on the frame. *n n* are handles projecting from a nut, which, on being turned, elevates or depresses the table F as may be required. E, Fig. 1135, is the handle to the shipper.

1135.



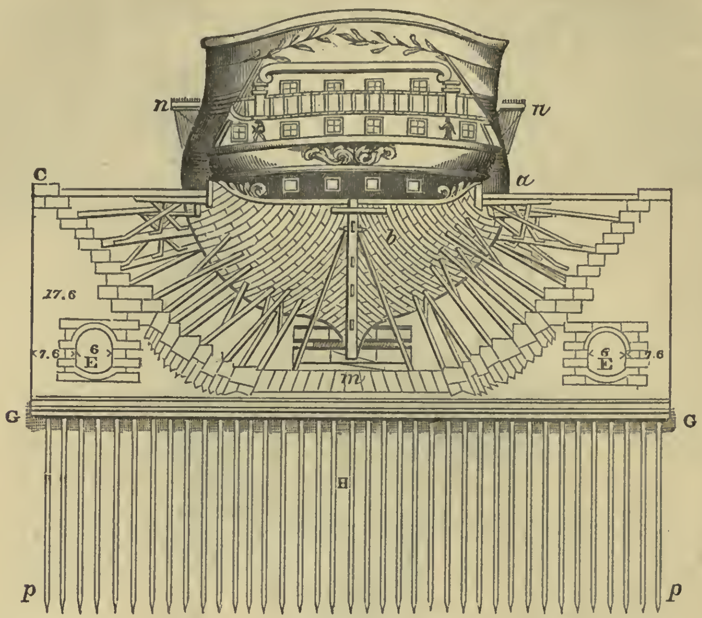
SCALE.—2 feet=1 inch.

A machine of gigantic dimensions has been constructed by Nasmyth for the Great Western Steam Navigation Company.

In this machine, the entablature carrying the upper end of the boring-bar is supported on two massive pillars of masonry, placed one on each side of the boring-bar. The feed motion of the cutters is novel and ingenious in the extreme; it consists, primarily, of an internal screwed collar fixed on the upper surface of the entablature, and surrounding the boring-bar. A train of geering, terminating in a pinion working into a rack running down the side of the boring-bar, is attached to the latter and revolves with it. The first wheel of the train is a species of crown-wheel, its teeth being set at right angles to its axis of motion; this geers with the internal threads of the screwed collar before-mentioned, so that by this means the train is set in motion by the revolution of the bar, and the cutter-boss, which is attached to the lower end of the rack, is raised and lowered at pleasure.

Mr. Walton, of Leeds, has introduced a highly effective boring-machine, with columnar framing intended principally for boring the apertures in the tube-plates of locomotive-engines. The machine is capable of drilling a series of parallel holes on a surface of five feet square, without refixing the object under operations, the tool-holder and the table being moveable at right angles to each other. This boring-machine may be considered as a magnified drill, as the spindle is fed longitudinally, no cutter-boss being attached. The framing consists of two plain columns, coupled at the top by a suitable entablature, and carrying two other transverse beams for the support of the drill-spindle and driving-geer. The self-feeding motion may be worked by hand.

1136.



Section on *b*.

DRY-DOCK, U. S., Brooklyn. *History of the Commencement and Progress of the U. S Dry-Dock at the Navy Yard, Brooklyn.*

New York was originally selected in 1794, as one of the points for the establishment of a naval depot.

In 1826, Col. Loammi Baldwin, a civil engineer of great skill and science, examined the harbor of New York, to ascertain the feasibility of constructing a dry-dock of sufficient size to receive a ship-of-the-line.

Locations for a similar purpose were examined at Boston and Norfolk, which led to the commencement of dry-docks at both of those places in 1832, and their completion in 1836.

In March, 1835, Congress authorized an examination for a site for a dry-dock at New York, and appropriated $100,000 for commencing it.

In the following June, Col. Baldwin examined the vicinity of the Navy Yard, and reported very favorably upon the facility for constructing such a work, nearly on the site where the present dock has been built.

In March, 1841, Congress made an appropriation of $50,000 for commencing a dry-dock at New York, and in August, Edward H. Courtenay, professor of Civil Engineering at the National Academy at West Point, was appointed chief engineer of the work.

Mr. Courtenay remained in charge of the work one year, during which time there was expended the sum of $35,264.75 on the coffer-dam, and erecting workshops, and providing tools, &c., for carrying on the work.

The succeeding Congress failed to make a further appropriation for the dock, and all operations were suspended in August, 1842.

At the close of this session Congress appropriated $100,000 for the construction of a floating dry-dock at New York, if the plan should be approved of by the Secretary of the Navy.

A commission was formed of naval officers and engineers, to investigate the merits of the different plans of floating-docks, as compared with the walled stone-dock, and also to determine the best plan of a floating-dock.

They reported in favor of the walled stone-dock as the best, and the "balance" as the best of the floating-docks.

In the naval appropriation bill of 1843, Congress directed an examination of a project for constructing a dry-dock in the city of New York, on the plan of using the Croton water as an elevating power, and an investigation of the best plan of a floating-dock.

W. P. S. Sanger, the Engineer of the Bureau of Yards and Docks, was directed to examine and report on these subjects, which he did adversely to the project of using the Croton, and the "Sectional" as the best plan of a floating-dock.

In February, 1844, Hon. Henry C. Murphy, a member of Congress from Kings Co., N. Y., took up the subject with great interest and energy, and presented the matter to Congress in a very able report.

To his exertions at this time may be mainly attributed a law that was passed in June following,

directing a resumption of the work on the site and plan previously determined upon, appropriating the unexpended balance of a former appropriation, amounting to $129,100.

In August, 1844, Gen. Wm. Gibbs McNeil, formerly an officer of the army, and then a distinguished civil engineer, was appointed chief engineer, and the works were resumed in October following.

Under this gentleman's direction considerable progress was made in the construction of the coffer-dam, and the removal of the excavation, and in preparing the plans and arrangements for conducting the work.

In March, 1845, Congress appropriated $150,000 for continuing the work, and it was placed under the direction of the Engineer of the Bureau, Mr. Sanger, until February, 1846, when Wm. J. McAlpine was appointed engineer in chief.

Congress has made the following appropriations:—

March, 1835	$100,000
Do. 1841	50,000
Do. 1845	150,000
August, 1846	250,000
March, 1847	275,000
July, 1848	350,000
March, 1849	490.000
Total,	$1,665,000

The progress of the work has been much retarded in consequence of the frequency with which its officers have been changed.

In 1835, Col. Baldwin expended the sum of $5,000. From August, 1841, to August, 1842, Mr. Courtenay expended $35,264.75. From August, 1844, to March, 1845, Gen. McNeil expended $114,675.83. From March, 1845, to February, 1846, Mr. Sanger expended $115,951.81; and from February, 1846, to the present date, (October 1st, 1849,) Mr. McAlpine has expended $1,147,310.39—making the whole amount of expenditure $1,418,198.78; and contracts have been made amounting to about $250,000 more.

A description of the Location *and* Construction *of the Dry-Dock.*—The dry or graving dock is a walled basin sunk below the level of the sea, to allow vessels to float in and remain while undergoing repairs. The water is removed from the basin, and the vessel is supported by shores resting on the bottom and sides.

In many parts of the world the rise and fall of the tide is sufficient to allow the vessels to float in at high, and become dry at low tide. When the tide is not sufficient for this purpose, it is necessary to remove the water by pumping.

The tide in the harbor of New York rises four feet seven and a half inches above mean low-water. The highest tides during the heaviest gales do not exceed eight feet above this mark, and the greatest range between low and high tide does not exceed ten feet.

The government dock-yard occupies the Wallabout bay, an arm of the East River, between the cities of Brooklyn and Williamsburg, on Long Island, and directly opposite the private dock-yards in the city of New York. The bay forms a fine harbor of sufficient capacity and depth of water to receive a large navy.

The dry-dock which is just being finished, and which it is now proposed to describe, is situated on the convex side of the channel of the Wallabout, near the northwest corner of the Navy Yard. It has been chiefly excavated, but the lower end of the dock was built on the edge of the channel.

This part of Long Island is a diluvial formation, composed of a coarse, sharp, red, and yellow sand and gravel, interspersed with boulders of trap and greenstone rock, some of which are of an enormous size, and will weigh several thousand tons.

The site selected for the dock is of more recent formation. The superstratum is formed chiefly by vegetable decomposition; below this, for a depth exceeding one hundred feet below tide, is a quick-sand formed by the debris of the rocks in the vicinity, brought down and deposited with alluvial matter by the East River, which at this place is expanded to three times the width it has above and below, and the velocity of the water correspondingly reduced.

This material is an almost impalpable sand, containing a large proportion of mica. When confined and undisturbed, and not mixed with water, it is very firm and unyielding, and presents a strong resistance to penetration. When saturated with water, it becomes a semi-fluid, and is moved by the slightest current of water passing over or through it.

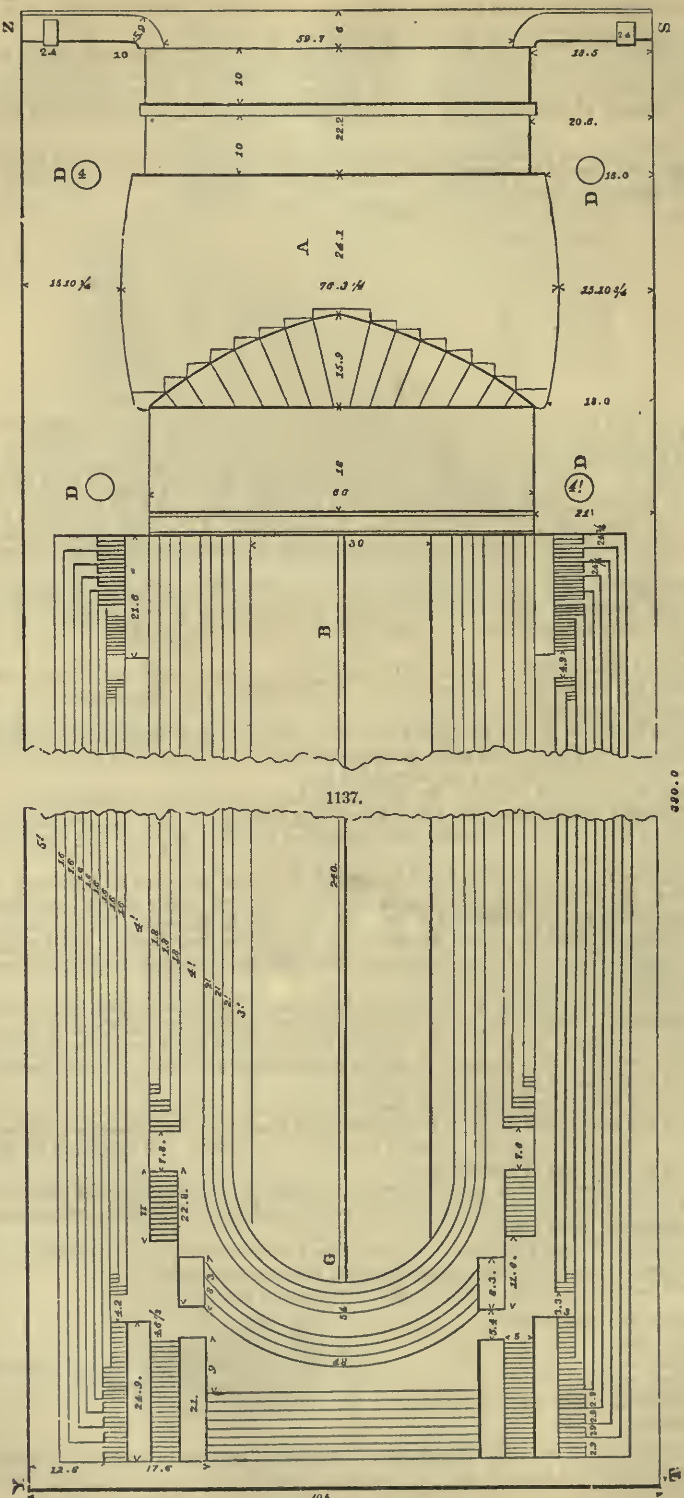
Borings were made to a depth of sixty feet below the level of the foundation, and the same material was found to extend to that depth. Small veins of coarse sand were occasionally encountered, through which flowed springs of fresh water.

It was on this material that the coffer-dam was to be constructed, to exclude the tide-waters, and a foundation prepared to sustain the enormous weight of the superstructure.

The work will now be described under the following general heads, viz:—

Dimensions of the structure
The coffer-dam.
The earth-work.
The bottom springs.
The foundation, apron, and pile-driving.
The masonry.
The gates.
The pumping engines.
The pump-well, culverts, and engine-house.
The machine and tools used; and
The cost of the work.

Dimensions of the Structure.—The pit which was excavated covered an area of over two acres at the top, and over one acre at the bottom. It was sunk about forty-two feet below the surface of the ground, and thirty-seven feet below mean high-water.



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The coffer-dam in front was four hundred and seventy feet long, and from sixty to one hundred feet wide. The wings were one hundred and seventy-five feet long, and from fifteen to thirty feet wide.

A double row of sheet piling protection-timbers were extended entirely around that part of the pit which was not protected by the coffer-dam.

The foundation is three hundred and ninety-two feet long, and one hundred and sixteen feet wide.

The main chamber is two hundred and eighty-six feet long, and thirty feet wide on the bottom, and three hundred and seven feet long, and ninety-eight feet wide on the top; and by using the floating-gate instead of the folding-gates, an additional length of fifty-two feet may be obtained. The least width is at the hollow quoins, where the walls are sixty-six feet apart at mean high-water line. The least depth of the dock is over the mitre-sills, where there is twenty-six feet of water at mean high-tide. The whole height of the walls is thirty-six feet.

The Coffer-Dam.—Before the excavation could be extended below the surface of the water of the bay, it was necessary to exclude the tide, and to provide for the removal of the water which would collect in the pit.

As the excavation was required to be carried to a great depth, (thirty-seven feet below mean high-tide,) it became necessary to provide a strong and tight barrier to resist the pressure and percolations of the tide-water.

The original dam was built as follows:—

Three rows of contiguous square piles were driven entirely around the lower end of the proposed excavation, leaving two intervals of ten and twelve feet between them. These piles were secured at the top, and at the level of low-water, by horizontal wales and iron tie-bolts.

The dams were filled with the silt which was taken from the excavation.

The piles were of yellow-pine timber, thirty-five to forty feet long, fifteen inches square, and sawed to parallel sides. A portion were tongued and grooved; but on examination it was found that from the difficulty experienced in driving, the piles swerved aside, and fractured or drew out from the tongues. The wales were of oak, twelve inches square, bolted once in ten feet, with bolts two inches in diameter.

On the first trial of this dam, (in February, 1846,) it was forced inwards by a pressure of less than ten feet head of water, and by the time the excavation was taken down, so as to bring a head of thirty feet of water against the dam, the water of the bay forced its way through the sand beneath the piles, and burst into, and filled the pit.

This breach occurred in July, 1846, at the northeast angle of the dam. It was repaired, and in September following, a similar breach occurred at the northwest angle of the dam.

The first breach occurred without warning, after the workmen had left. The first indication of the September breach, was an increased flow of water in one of the bottom springs, which was situated fifty feet from the nearest part of the coffer-dam.

The water flowing from this spring had previously been fresh; it was observed to change alternately from fresh to salt, several times within a few minutes, and in less than an hour had increased to five times its former quantity, and soon after brought up volumes of the black mud which overlays the quicksand in the channel of the bay. The direction of the breach was soon developed by the sinking of the coffer-dam, some of the piles in which settled down vertically from five to six feet.

After the occurrence of these breaches, it became necessary to reconstruct a dam.

This was done with piles from ten to fifteen feet longer than had been before used. The new dam which was placed on the outside of the old one, was made from thirty to forty feet wide, so that the weight of the earth would break down into any passages which the water might form through the loose soil on which the dam rested.

In the narrow dams it was found that the earth adhered to the timber on the sides, and that the cavities formed by the filtering of the water, became very large before any of the earth broke down to fill them.

The new dam was filled with gravel, containing loam, sand, and coarse stone. The gravel was filled in water thirty feet deep, and to prevent the stone from separating from the other materials in the descent, it was discharged in large quantities from boats with drop bottoms which contained one hundred tons. A row of piles was driven on the inside of the original dam, to a depth from twelve to fifteen feet below the proposed level of the foundation. A heavy bank of coarse gravel was filled on the inside of the dam, extending up to the lines of the foundation.

The material on which the dam rested, was so unstable, that although the piles penetrated it from fifteen to twenty-five feet, yet the dam continued to yield to the pressure, and was only sustained by the closest watchfulness, and the most prompt application of remedies.

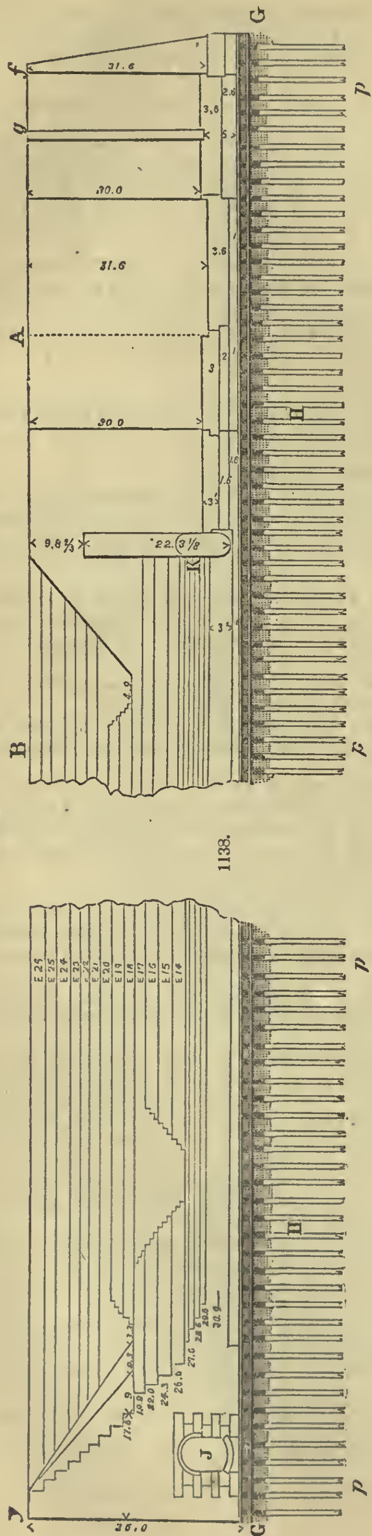
As long as the excavation was in progress, there was no opportunity to obtain any support from the inside, and whenever it could be done, chain cables were attached to the dam, and secured to mooring blocks on the shore. These cables, made of iron two inches in diameter, were repeatedly broken. On one occasion six of them broke during one night.

The removal of the excavation adjoining the dam was not effected any faster than it could be followed up by the foundation piling, and this was done in trenches, leaving abutments of earth on each side. Timber shores were extended from the foundation to the dam, before the intermediate sections of earth were removed.

In like manner the rear work of the masonry on the foundation was at first laid in sections, and braces extended from it to secure the dam.

The thrust upon these braces at one time was so great, that it moved a mass of masonry exceeding two hundred and fifty tons weight.

The earth in the dam was subject to a continued waste on the side adjoining the bay, by the action



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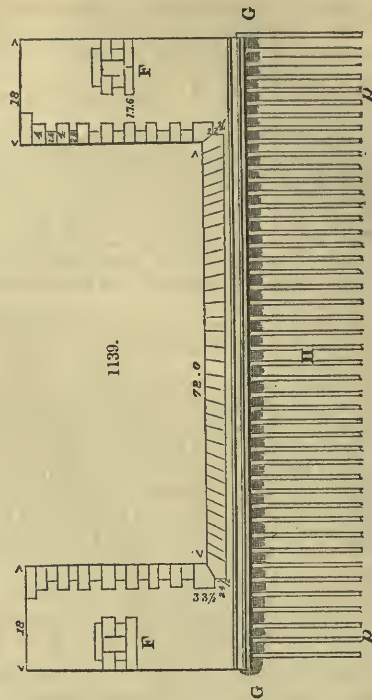

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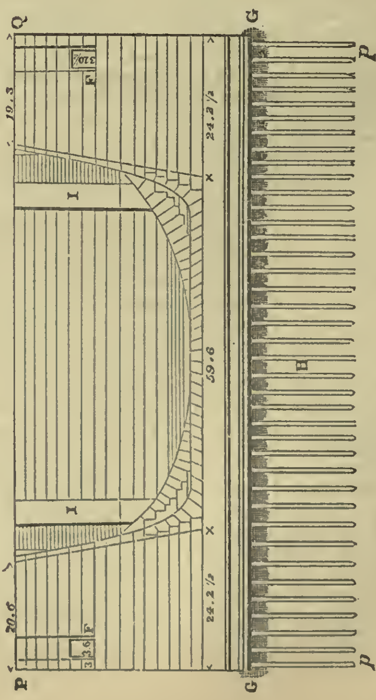


1140.

of the water flowing through the joints of the piling; but this waste gradually decreased, until it became of but little importance.

The whole number of piles driven for the coffer-dam is 3,504.

Earth Work.—That part of the excavation of the pit which was above the level of low-water was taken out before the coffer-dam was constructed. There was also about ten feet of the earth below the water dredged. The semi-fluid state in which the material was found after the water had been pumped out of the pit, rendered its removal very difficult and tedious.

When the excavation had been extended to a depth within about six feet of the level proposed for the foundation, springs of fresh water burst up through the crust, and discharged very copiously.

It was found necessary to use tight vessels in removing the earth, because when the water mixed with the sand, it became so fluid, that it would escape almost wherever water would flow. Boom derricks were used to some extent in the removal of the excavation from the pit. Dumping tubs were suspended from the end of the boom, which, when filled, were hoisted to the level of the ground by steam-power. The chief part of the excavation, however, was taken out in cars, which, when loaded, were hauled up the inclined planes by steam-power. These cars possess an advantage over the earth-cars commonly used for this purpose, as they were hung very low, not above thirty inches from the top of the ground to the top of the box. This saves the labor of shovelling the earth twice to load the cars. They dumped between the axles and between the rails.

The walls were backed up with gravel, as fast as the masonry was laid.

Puddle walls were extended from the sides of the masonry to cut off the passage of water along the walls.

The Bottom Springs.—These were met with, as before stated, when the excavation had nearly reached the level proposed for the foundation, and were the cause of the greatest difficulty which was encountered in laying down the foundation.

The water which flowed from them was entirely fresh, and evidently came from a source higher than the tide-water. The temperature was 53° in January, and 55° in August. The temperature of the water in the bay at the same time was 43° and 46°, and that of the atmosphere was 40° and 90° at the same dates. The flow was not affected by the rise and fall of the tides.

The strata through which the springs flowed, were evidently at a great depth (not less than thirty feet) below the foundation, and the veins of water of the different springs, even those contiguous, had no connection with each other.

The difficulties caused by these springs did not proceed from the mere flowing of the water; but this, as it came up, brought with it large quantities of sand, so fine and impalpable, that it would insinuate itself through the smallest interstices, and if allowed to flow in this manner, would soon have endangered the surrounding works. Nor could the water be checked with safety, as the pressure was sufficient to raise the foundation, however heavily it could be loaded. It became necessary, therefore, to provide for the flow of the water, and at the same time check the removal of the sand.

After repeated trials, it was found that the level of the outlet of the springs could be raised to a height which would not disturb the foundation, and would yet be sufficient to check the velocity of the water so much, that it would not disturb the sand through which it flowed.

The largest spring discharged (in 1848) ten gallons per minute. When the water was allowed to flow at a level, twenty-six feet below low-water, it discharged thirty-eight gallons per minute, which contained twenty-seven ounces of fine sand; at a level twenty-two feet below it discharged thirty-three gallons, containing seventeen ounces of sand; at a level nineteen feet below, it discharged twenty-two gallons, containing four ounces of sand; and at a level seventeen feet below low-water, the water flowed unmixed with sand.

One of the most troublesome and refractory springs was encountered at, and near the pump-well, at the northeast corner of the dock.

The first evidence of its effect was the undermining and settling of the piles driven to support the pumps and engine, and rendered it necessary to change the pump-well; but the spring followed, and compelled another change of the well. The spring was driven out of the old well by filling it with piles, but it immediately burst up among the foundation piles of the dock near by. In a single day it made a cavity in which a pole was run down to the depth of fifteen or twenty feet below the foundation; one hundred and fifty cubic feet of cobble-stone were thrown into this hole, which settled ten feet through the night, and fifty cubic feet were thrown in the following day, which drove the spring to another place, where it undermined and burst up through a body of concrete two feet thick. This new cavity was repeatedly filled with concrete, leaving a tube for the water to flow through, but in a few days it burst up in a new place, where it soon undermined the concrete, and even the foundation piles, so that they settled from one to three inches. These piles were thirty-three feet long, and had been well driven by an average of seventy-six blows from a hammer weighing two thousand two hundred pounds, falling thirty-five feet at the last blow, which did not move the pile over half an inch.

These alarming results rendered paramount the adoption of the most thorough and speedy measures to prevent any further injury from this source. Accordingly, as many additional piles as could then be put in the space were driven, and those put in before were then driven from eight to twelve feet lower, by means of followers. The old concrete was removed to a depth twenty inches below the top of the piles. An area of about one thousand square feet around the spring was planked; a floor of brick was laid in dry cement; and on that another, also of brick, was set in mortar, made of Roman cement; the space was next filled with concrete, and the foundation completed over all in the usual manner, and with the greatest dispatch. Several vent-holes were left through the floors and foundation. After a few days' interval, when the cement had become well set, the spring was forced up about ten feet, at which level it ever after ran clear, and without discharging sand, and gave no further trouble.

The other bottom springs, some forty in number, have been of a like character, but the successful result obtained in the treatment of that above described, led to the adoption of the same plan with each, and with similar results.

Two of the springs were accidentally closed by freezing in 1848, and forced up, in one case eight hundred, and in the other twelve hundred square feet of the foundation. The rising took place between the lower timbers and the planking, lifting also the first course of the stone floor, which was from twelve to fifteen inches thick.

None of the springs were closed until the inverted arches of masonry and side walls had been laid, and the cement had become well set. The pressure on the bottom of the floor is so great that the water sweated through the joints, but did not disturb the stone.

The arrangement proposed to be accomplished, was to bring up all of the springs through the foundation, and have no pressure upon it, until the masonry was laid, and the cement had become well set; but there were many minute veins of water that were unnoticed when the foundation was laid, which exerted a force upon the cement joints, and rendered its setting very slow and tedious. These joints will require a twelvemonth or more to become impervious to the water.

The whole amount of water which came into the pit for the last year was from these springs; none leaked through the dam. The quantity which flowed in was seven hundred cubic feet per hour.

The water was removed from the pit by a steam-engine of twenty-five horse power, driving two plunger pumps of fifteen inches diameter, and five feet stroke, which discharged six hundred cubic feet per minute.

Foundation, Apron, and Pile-Driving.—In 1835, Col. Baldwin examined the proposed site of the dock by borings, which he extended in several places to a depth exceeding eighty feet below tide. These borings brought up sand and clay, and also fresh water, but touched no rock.

Col. Baldwin remarks, "Upon careful examination of these circumstances, I have no doubt a dry-dock may be safely founded at Wallabout bay. Should piling for the foundation be thought necessary, which can best be determined in the process of excavating, the piles cannot be driven deep in such soil, and will have similar or better resisting materials than those hitherto used. The construction of a dock in the yard, however, will be more difficult than either of those built before, (at Charleston and Norfolk.")

In 1842, Mr. Courtenay commenced driving the piles for the coffer-dam, and remarks, "During the progress of the work we were enabled to form a very satisfactory opinion, as to the character of the soil upon which the dock was to have been founded, and the frequent examinations then made resulted in the conviction, not only that the substratum was sufficiently firm to resist, without danger, the pressure arising from the weight of the contemplated structure, but that the nature of the soil was far better adapted than had been supposed, to resist the percolation of water through the dam."

A deposite of clay mixed with a large proportion of very fine sand, which covered the northeast portion of the pit, for several feet in depth, probably led to the favorable conclusions of these gentlemen.

The soil, as was developed by the excavation, is as has been previously described, and there is but a very small portion of clay in any part of it.

The borings which were made during the progress of the work extended to a depth forty feet below the foundation. Specimens have been preserved of the soil taken from various parts of the dock, and at every change in depth, including that which was brought up by the borings. Sets of these specimens have been deposited in various public institutions through the country.

A trial-pile was driven in June, 1846, to the depth of forty-five feet below the foundation. It was a round stick of spruce, twenty inches diameter at one end, and fourteen at the other, and forty-nine feet long. It was shod with iron, and was driven by a hammer weighing two thousand and twenty four pounds, falling from its greatest elevation, thirty-five feet.

For the first hundred blows the hammer fell but a few inches; the next two hundred and sixty blows drove the pile thirty inches in forty-six minutes; the next two hundred and sixty-five blows occupied an hour, and drove the pile from half an inch to one and a half inches at each blow; the next one hundred and ten blows in an hour, averaged one and a quarter inches at each blow, the hammer falling at the last blow thirty-four feet. The pile subsequently received about two hundred blows through the medium of a follower, which drove it an average of half an inch to each blow.

In June, 1847, a pile was driven forty-three feet by Nasmyth's steam pile-driver; and then another pile fifteen feet long, driven on top of the first, making a total depth driven into the earth of about fifty-seven feet.

The first pile was driven forty-two feet, by three hundred and seventy-three blows in seven minutes, as follows: Four blows, four inches each; eight blows, three and a half inches each; twenty-two blows, three inches each; twenty-five blows, two inches each; forty blows, one and three quarters inches each; fifty-six blows, one and a half inches each; thirty-two blows, one and a quarter inches each; sixty-four blows, one and an eighth inches each; seventy-three blows, one inch each; the last forty-nine blows, half an inch each blow.

The second pile was driven fifteen feet by two thousand four hundred blows in forty-three minutes, as follows: Thirty-three blows, three-eighths of an inch at each blow; seventy-three blows, one-fourth of an inch each; one hundred blows, one-eighth of an inch each; eight hundred blows drove it together eighty-eight inches; three hundred blows, twenty-four inches; three hundred blows, twelve inches; four hundred and fifty blows, eleven inches, and the last three hundred and forty blows together drove the pile five and a half inches.

The movements of these piles indicated the continuance of the same material to the depth which they reached; and the uniformly increasing resistance, as the pile penetrated the earth, gives very favorable evidence of the support which the piles afford, when they are thus driven to the point of absolute resistance.

The soil required very hard driving to force the pile into it, and as long as the material was undisturbed, the subsidence of the sand around it added greatly to the firmness of the foundation. Yet the springs were liable to disturb and loosen the soil around the piles, and, as has been previously stated, destroy their value as supports.

To prevent the wasting effects of the springs, it became necessary to put down the foundation in small detached pieces, and frequently to drive the piles at a level, sometimes to the extent of six feet above the proper plane. When one of these pieces was taken in hand, the earth was removed, and the concrete, timber, &c., put in without a moment's cessation; for the springs would in a few hours render the earth semi-fluid, which had before been compressed to great firmness by the insertion of the piles.

It was originally supposed that piles driven at distances of three feet from centre to centre, and twenty to twenty-five feet long, would afford a sufficient foundation to the superstructure; but from the fear that changes might take place after the foundation was put down, it was determined to drive as many piles as could be forced into the earth. The chief part of the piles were driven to the point of absolute resistance, and whenever a hammer of two thousand pounds weight, falling thirty-five feet, drove the pile for the last few blows exceeding three inches per blow, another and longer pile was driven alongside.

Great care was taken in registering the performance of all the piling engines used in constructing the foundation of the dock; the depth driven by every blow that has been given to every pile was recorded, and from these data the following averages have been made. The average number of blows received by the piles was seventy-three; the average depth driven by the first five blows is eight inches each; by the middle five blows, six inches each; and by the last five blows, one inch each blow.

The whole number of bearing-piles in the foundation is 6,539, besides 1,744 sheeting-piles, which serve also as bearing-piles. The piles are chiefly round spruce timber, from twenty-five to forty-five feet long, averaging fourteen inches diameter at the head. The average length of the piles as driven, is thirty-two feet.

The sheeting-piles were yellow-pine planks, five inches thick, and from twelve to twenty-five feet long. They averaged fifteen and a quarter feet long. They were tongued and grooved, and were driven entirely around the foundation, and four rows across the pit.

The piles were protected at the head by a band of wrought-iron, three by one inch, made of the toughest iron that could be procured. One ring would generally drive two piles before it burst, and by welding it could be used three times. Occasionally the point was shod with iron, but this did not increase the facility of driving, as the resistance was caused by the friction on the sides of the pile.

The hammers which were used were generally about twenty-two hundred pounds weight. Several were used from three thousand to four thousand five hundred pounds, with economy and effect. The arger hammer did not injure the pile as much, and it was driven in less time, and with a less umber of blows, and the same power as was applied to the smaller hammer.

The leaders of the machines were from thirty-five to fifty feet long.

The hammers were hoisted by men working with a crank, and on a treadwheel, and with horses, but chiefly by steam-power. The expense of these several methods of driving piles are in the order in which they have been stated above.

A contract was made for the use of one of Nasmyth's steam pile-drivers, and one of his best machines was imported. Unfortunately, however, the machine was constructed too light to perform the severe labor to which it was here subjected.

When in order, it produced the most astonishing results—driving the piles in less than one-third the time or expense of any other known method.

Its principle consisted in very rapid short blows, with a very heavy hammer. The steam cylinder was inverted over the hammer, to which it was connected directly by the piston-rod; and the hammer, which weighed two and a half tons, was hoisted by the stroke of the engine at every revolution. Both the cylinder and the hammer, were supported by the pile itself, to which it was loosely attached by a deep cap or band. The cylinder moved up and down, alongside a spar, and the steam was conveyed to it by a flexible tube leading from the boiler on the frame below. The hammer made about sixty blows per minute.

The concrete masonry which was used in the foundation was made as follows:

A soft mortar was made of one part of hydraulic cement, and two parts of clean sharp sand; into this was thrown five parts of stone, broken, not to exceed one and a half inches in diameter. The mass was thoroughly mixed, and immediately thrown into the place where it was required for use.

The foundation was put down in the following manner:

The bearing-piles were sawed off at a level thirty-three and a half feet below mean high tide. The earth was removed to a depth two and a half feet lower, which space was filled with concrete masonry.

The piles were capped with yellow-pine timber, twelve by fifteen inches scantling, trenailed and bolted to the piles, and laid transversely to the axis of the dock. The spaces between the timbers were filled with concrete. Yellow-pine plank three inches thick were jointed, and closely laid on and spiked to the timbers. On the top of the plank another set of timbers of the same size were laid, breaking joints with those below. The spaces were filled with concrete, and covered with plank in the same manner as the first floor.

At the foot of the dock an apron is extended for thirty feet in front, to protect the lower end of the foundation from undermining.

It is composed of timber and plank, and supported on piles, with concrete masonry between and below the timbers, in the same manner as the foundation of the dock. It is prevented from floating by trenailing and bolting to the piles, and by inserting dovetailed stone between the ranges of timbers

The tide tables which had been kept for several years at this station, showed that the level of the foundation should be placed six inches lower than had at first been supposed to be necessary It was accordingly assumed at a level which would give twenty-five feet of water on the mitre-sills at high tide, for two-thirds of the days in the year.

The Masonry.—It is believed that no modern structure in the world surpasses this, in the size of the stone, in the accuracy of their workmanship, and their durability.

The quantity of masonry which has been laid to form the walls of the dock is 23,375 cubic yards, and in the draining and discharging culverts, and the engine-house, and other masonry connected with the dock, there is 5,250 cubic yards.

All of the facing-stone has come from the Sullivan and Frankfort quarries in Maine, and New London in Connecticut.

The interior stone was chiefly obtained from the Staten Island and the Highland quarries in New York

A system of inverted arches occupies the whole extent of the lower part of the structure, and serves not only to distribute the weight of the walls over the whole surface of the foundation, but to resist the immense hydraulic pressure from beneath. The floor of the main chamber is first formed of a tapering course of cut-stone, twenty-seven inches thick at the head, and twelve inches thick at near the mitre-sill; the second course of stone is uniformly three feet thick, and the arches are extended to a height nine feet above the floor on each side. The floor of other parts of the dock is made in a similar manner.

The mitre-sills are immense blocks of granite; the key-stone is estimated to have weighed about fifty tons before it was cut; its weight is now 43,300 pounds; sixteen similar stones form the mitre-sills, and the smallest stone weighs 13,300 pounds.

The floor of the chamber is level on the bottom for thirty feet wide, and the sides are carried up in steps or altars for the convenience of shoreing the vessel and working under her bottom, as represented in Fig. 1136, where the Ohio, ship-of-the-line, is shown "in dock," sustained by the keel-blocks and shores.

The side walls are laid up with English bond, alternate courses of stretchers and headers; the stones in the alternate courses are of the same length which gives what is termed "plumb-bond," although the stones in the same course differ in length, a variety of lengths having been previously determined upon to facilitate the quarrying of the stone. These lengths have, however, been so arranged as that adjoining stone do not differ to exceed three inches, and increase and diminish gradually from the shortest to the longest stone. The difference in length is therefore imperceptible.

The courses are chiefly twenty-four inches thick, a few near the bottom being twenty-seven inches thick. The beds of the stone in the stretcher courses are from three to three and a half feet broad, and in the header courses are from four to five feet broad. The length of the headers is from three to four feet, and of the stretchers from six to eight feet. The headers are in all cases one-half of the length of the stretchers.

The smallest stone in the face exceeds three thousand pounds, and the average is about six thousand pounds. Many of the coping and other large stones exceed fifteen thousand pounds. The interior stones are also large, and will average upwards of fifteen hundred pounds.

The facing stones are all laid to a joint not exceeding three-sixteenths of an inch, and the joints are kept up full to the lines for the full depth of the stone.

The facing stones have been backed up with a course of scabbled stone cut to the same thickness, and laid to joints not exceeding half an inch.

The interior and rear of the wall has been laid up with coursed rubble, which has been so selected that either one or two courses made up the thickness of the facing course.

The following extract is taken from the contract for the granite facing:

"All of the stone must be of the most durable description of granite, entirely free from sap, stains, or seams, and obtained from quarries which may be approved of, by the Engineer in charge of the work; all of the stone which show in the chamber must be of the same color and general appearance.

"Patterns for quarrying and cutting the stone will be furnished by the government; on all the arch-stones full corners and edges will be required on the back lines of the stone; all of the stone will be delivered cut, except such stone as may be directed to be delivered unwrought, in which case they shall be quarried out without any unnecessary excess of stone, but of sufficient size to fill the patterns. The cut-stone designed for the facing of the work must be delivered with perfect edges on the show-lines, and none will be received which are in any way marred or nicked.

"The stone must be delivered in the order in which they are required for use, as far as practicable.

"In the courses of the chamber above the inverted arch, and in the other walls where an additional width of bed is permitted, the minimum size will be given in the bills, but stone of greater width will be received.

"Suitable 'lewis' holes shall be drilled in the bed, or such other surface as may be directed, to receive a lewis of sufficient size to suspend the stone with safety.

"Such cranes, machinery, and assistance as may be required for discharging the stone from the vessels at the Navy Yard, will be furnished by the government.

"The cutting which is required to be done on the face of the stone which shows, and also on the builds of the outer stone, shall be as hereinafter described as first-class work; that required on the beds, builds, and joints, shall be as hereinafter described as second-class work; that required on the rear of the front and interior stone, shall be as hereinafter described as third-class work. The beds and joints must be dressed up full to the square, and no slack joints will in any case be permitted. The cutting will be required to be done in the following manner, to wit:

"*First-class work.*—The arris must be kept clean and sharp, with fine-cut drafts run around the surfaces to be dressed. Within these lines the surfaces must be taken down fair and even with a patent hammer of eight plates. No holes or depressions of any kind that will show in the face will be per-

mitted; and the dressing with the hammer must be level and square, so as to present a smooth fair appearance.

"*Second-class work.*—A good arris must be kept; clean draft-lines must be run around the surfaces to be dressed. Within these lines the stone must be dressed down to a fair even level surface, with a common pean hammer. No depressions of any kind will be allowed within six inches of the face; none which exceed six inches in diameter, or one inch in depth, or where they shall together exceed one-fourth of the surface in which they occur.

"*Third-class work.*—Draft-lines shall be run around the surfaces to be dressed. Within these lines, they shall be pointed down to a fair even surface and finished with a pean hammer, so as to make good close work, of not exceeding half an inch joint. No cavities or depressions will be allowed which exceed eight inches in diameter, or one and one-half inches in depth, or when they shall together exceed one-fourth of the surface in which they occur."

The following extract is taken from the contract for the backing-stone.

"They shall be of a sound durable description of granite or gneiss, free from sap or seams, split out by wedges in blocks, with parallel beds and sides; at least three-fourths of the bed, and one-half of the build, must have a fair level bearing-surface; the vertical joints must be split down at right angles to the bearing surface of the stone; the stone must all be drilled on the top bed to receive a lewis of such size and form as shall be directed. The dimensions of the stone must in no case be less than the following: viz., length, two and one-half feet; width, one and one-half feet; thickness, eight inches. And no stone larger than the following will be received: viz., length, eight feet; width, four feet; thickness, two feet; and the stone must average not less than twelve cubic feet."

The whole of the masonry was laid in mortar made of one part of Hydraulic cement and two parts of clean sharp sand; the cement used was from the celebrated "Lawrence and Newark" manufactories, at Rosendale, New York.

It was required to be fresh ground, very fine and lively, and transported under cover in barrels, containing about three hundred pounds; the barrels to be made of seasoned air-tight staves, and to have twelve hickory hoops, and each barrel to be well papered. Every tenth cask was subjected to the following tests: *first*, mixed up in flat cakes of two inches diameter, the moisture carefully dried from the surface by means of blotting paper, until it was set enough to bear one-fourth of a pound weight on a wire of one-twelfth of an inch diameter, and then put in water, where, after the lapse of not exceeding five minutes, it should bear one pound on a wire of one-twenty-fourth of an inch diameter.

Second, a similar-sized cake, after the lapse of five days' insertion in water, was required to bear a wire of one-twenty-fourth of an inch, loaded with fifty pounds.

Third, two bricks united by cement and put in water five days, must resist one hundred pounds before separating.

No cement was used until after it had stood the above tests. They were made with water at a temperature of 70°. The mean of a large number of these tests is as follows:

The time to dry in air, to bear one-fourth pound on a wire one-twelfth inch diameter, was 8 minutes.

The time to set in water, to bear one pound on a wire one-twenty-fourth inch diameter, was three and one-fifth minutes.

Force required to thrust a wire one-twenty-fourth inch diameter, through cakes of cement two inches diameter, and three-fourths of an inch thick, after being immersed in water 24 hours, 65 pounds.

do.	do.	48	"	70 "
do.	do.	72	"	75 "
do.	do.	15	days,	155 "
do.	do.	50	"	390 "

The joints of the whole masonry have been pointed up in the following manner: Cement and sand were put in an iron mortar slightly moist and made nearly into an impalpable powder; this was driven into the joint to the depth of an inch by an iron caulking tool, and the upper surface rubbed with a steel tool until it became very hard; in a few days this pointing was nearly as hard as the adjoining stones.

The masonry of the dock was laid up in an unprecedented short time. The first stone was laid May 12, 1847, but the foundation was not entirely completed until June, 1848. The first coping-stone was laid July 4, 1849, and the whole work completed during that season. This dispatch was owing to the systematic arrangements of the various operations, and to the number and capacity of the machines used in the construction. On the completion of the work it was found that there were no stone left on hand.

The prices which have been paid for the stone used in this work are as follows:

For the granite coping, hollow quoins, and other expensive stone, sixteen dollars per cubic yard. For the plain facing-stone, ten dollars; for the second class, nine dollars; and for the rubble stone, five dollars per cubic yard. For the fine cutting on the hollow quoins, checks, etc., one dollar per superficial foot; on the facing stone, forty cents; for the second class of cutting on the beds and joints of the facing stone, twenty cents; and for the third class of dressing on the interior stone, twelve cents per superficial foot.

The weight of a cubic foot of the several kinds of granite, sienite, and gneiss, used on this work is as follows: Sullivan, Frankfort, and Seal Harbor, 168 pounds; Blue Hill, 165; Quincy, 169; Millstone Point, 170; Breakneck, 169; Staten Island, 186; and Kips' Bay, 172.

The Gates.—The folding gates are similar to those used in canal locks, though of much greater dimensions. Such gates have usually been built of wood, though a few docks in Great Britain have them made with cast-iron frames, and covered with oak or sheet-iron.

The low temperature of the atmosphere in this climate renders the use of cast-iron dangerous where it is subject to violent concussions; to avoid this objection, Mr. McAlpine was induced to arrange a gate

made of wrought-iron, on an entirely original plan; they are the first iron gates which have been built in this country. They are made as follows:

Two leaves are to be erected so as to turn on the quoin posts, and secured to the masonry of the dock by steps and straps, and arranged to be worked by capstans in the walls, from which chains are extended to open and close the gates.

The frame of each leaf is composed of a series of horizontal curved bars of wrought-iron, bolted to the quoin and mitre posts, and covered on the outer side by a sheathing of boiler-plate, riveted and secured together by angle-iron.

The outer extremity of each leaf is supported by two rollers traversing on circular tram-plates, laid on and secured to the floor of the masonry.

The quoin-post is a cylinder of cast-iron. The mitre-post is made of wrought-iron, and a buffer of oak inserted where the two leaves come in contact. A similar buffer is inserted at the bottom of each gate where it comes in contact with the mitre-sills.

There are two valves in each leaf for the passage of water to and from the chamber of the dock. Each leaf is thirty-eight feet three inches long, and thirty-one feet high, curved on a radius of seventy-six feet seven inches on the outside of the gate. The gate is twenty-six inches wide at the quoin-post, and twenty-two inches wide at the mitre-post. The quoin-post is turned and planed to fit the quoins and collar-straps.

The horizontal bars are made of plates of wrought-iron, twenty-two inches wide and three-fourths of an inch thick, curved to suit the form of the gate, and made up alternately of three and four plates to each bar, and secured at the joints by splicing-plates.

The sheathing is made of boiler-plates, from ten to fourteen feet long, and two to four feet wide. The bottom courses are five-eighths of an inch thick, and they gradually decrease in thickness, and are one-quarter of an inch thick at the top of the gate; they are secured to the horizontal plates by means of angle-iron riveted to each. The horizontal joints are lapped, and the vertical joints are butted, and riveted, and chipped, and caulked, so as to be water-tight.

The mitre-post is made up of a plate of iron (welded) thirty-one feet long, twenty-two inches wide and one inch thick, set upright, with side pieces secured by angle-iron; the whole secured to the horizontal bars by shelf pieces of angle-iron.

The valves are made of cast-iron and set in a cast-iron frame, bolted to the bars of the gate. The valves are opened by screws placed on top of the gate.

The rollers are of cast-iron, eighteen inches in diameter, and set in a frame with a long rod and screw, by means of which the extremity of the gate may be raised at pleasure. On the top of the gate is placed a foot-walk, supported by iron bars, and a hand-rail of wrought-iron.

The capstans are geered, and the chain drum is provided with an ingenious arrangement for laying the chains which are extended to open and shut the gates.

India Rubber is inserted in the buffers.

The whole surface of the gates is painted, to protect it from corrosion.

The horizontal bars were originally designed to be welded in one bar and to be made of iron one inch thick, and the bars at the bottom of the gate placed twelve inches apart.

Some doubt having been expressed whether such a bar contained the requisite strength, a model bar of the same form and length proposed was made of four plates of iron, twenty-two inches wide and three-fourths of an inch thick, with lapping plates over the joints three feet long. This bar was first tested by loading it, with the ends secured and resting against abutments.

A weight of 92,000 pounds was put on the middle of the bar, which deflected it two inches; the yielding of the frame prevented any further weight being applied, but it was subsequently tried without abutments, and deflected three inches with 50,000 pounds; six inches with 65,000 pounds; ten inches with 71,000 pounds, and broke with 75,299 pounds; the fracture being a rent near the middle, extending up from the lower edge six inches.

For drawings and descriptions of the *floating gates* or caisson, see Gates, and for the machinery for clearing the docks from water, see Pumping Engine.

The Machines and Tools used.—A steam-engine, with a cylinder of fifteen inches diameter, and four feet stroke, was erected to drive the temporary pumps used for draining the work during its progress.

Two other steam engines, one of twelve and the other of five horse power, were used at times during the construction of the work. These engines were all fitted up with winding-drums, by which power was conveyed to the several machines.

The mud was hoisted out by tubs suspended from the booms of the derricks and by cars moving on inclined planes, which were elevated by means of a rope leading to the winding-drums of the engines. In a like manner the hammers of the piling-machines were elevated, and heavy stone were hoisted and lowered on the cranes and derricks.

Grindstones, saws, planing and groving and screw-cutting machines were also driven by the surplus power of the engine. The edges of the flooring-plank, and the grooving and tongueing of the sheet-piles were all done by machines driven by steam-power.

The drawings of some of the most useful of these machines will be found under the several heads of "stone-setting machines," "lewis," "crane," "derrick," "piling-machine," "stone jack," "pumping-engine," where a full description of them will also be found.

It remains only to state how these machines were applied. The stone were chiefly transported on cars; lines of railroad encircled the pit, from which branches led to within reach of each of the laying-derricks, the piling-derricks, and the discharging cranes. The stone were hoisted out of the vessels with the cranes worked by steam-power, and loaded on cars and transported to the stone-cutters' sheds or piling-derricks, where they were assorted and stowed away. Thence they were taken as required by the laying-derricks placed around the margin of the pit. The discharging-cranes were cheap machines. The piling-derricks were chiefly the old excavation-derricks refitted.

The Cost of the Work.—The amount which has been expended to the 1st of October, 1849, is $1,418,198,78. This sum has been classified under the following heads of expenditures, viz.:—

Offices	$69,418 17	Culverts and well	32,485 74
Coffer-dam	206,378 36	Temporary drainage and steam engine	105,139 07
Earthwork	149,802 58	Workshops	104,293 23
Foundation	127,250 03	Miscellaneous	6,566 41
Masonry	600,569 84		
Gates	16,295 35		$1,418,198 78

It is estimated that the sum of $420,000 will be required to finish the work; but in these amounts are included the value of machines and tools, the cost of constructing a machine-shop, and grading and levelling the Navy Yard, which are inappropriately charged to the dock, and which, if deducted, would make the cost $1,750,000.

Description of the Drawings. Fig. 1137 shows a plan of the masonry. The entrance to the dock is at S Z; near by is shown the groove into which the caisson or floating-gate is sunk. D D D D represent the four capstans which open and close in the two folding-gates. G B is a drain sunk below the level of the floor of the chamber.

Fig. 1138 represents an elevation of the walls, and also of the timber and pile foundation. The entrance to the dock is at *f*, the groove for the floating-gate. At A is the recess to receive the wing of the folding-gate when open. B to *y* represents the chamber in which the vessel is received. At K is the gallery leading to the exhaust culverts running through the walls, a section of which is shown at J. *p p p p* represent the piles which support the structure, on the top of which are shown the timbers and plank. In Fig. 1139 is shown a section of the walls through the point marked A on the plan and elevation, being the recess to receive the folding-gates when they are open. The culvert passages which are used to fill the dock are shown at F.

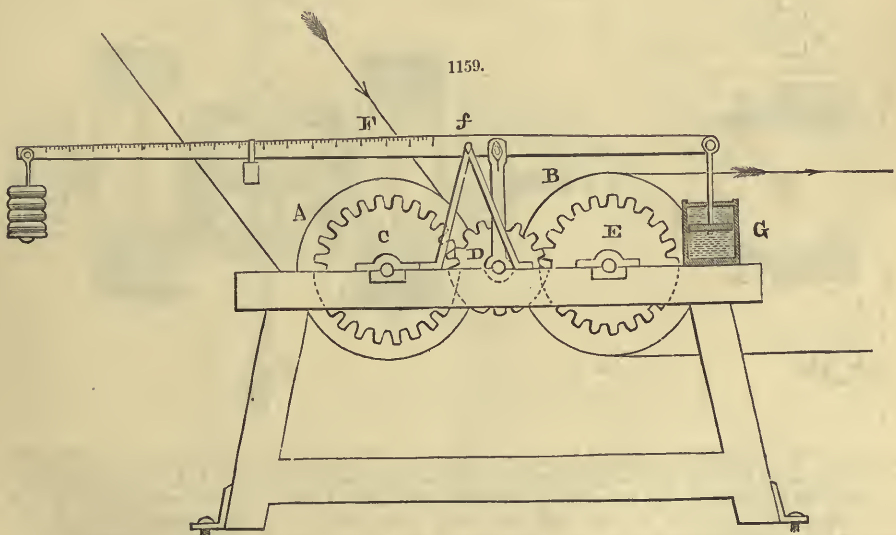
Fig. 1140 is an elevation of the entrance wall, showing the filling culverts at F, and the slides at the head of the dock for lowering timber by I.

Fig. 1136 represents a section of the dock in the receiving-chamber, with a line of battle-ship resting on the keel-blocks and shores. The exhaust culverts are shown at E. In all of these drawings the most important dimensions are marked in feet and inches, which obviates the necessity of any further description.

DYNAMOMETER. See Brake.

DYNAMOMETER, *invented by S. Brown, of Lowell:* the principle of which consists in measuring the power used by weighing the strain on an intermediate geer.

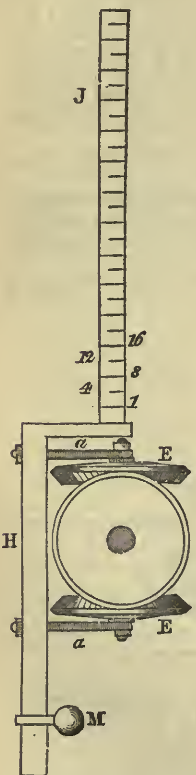
1159.



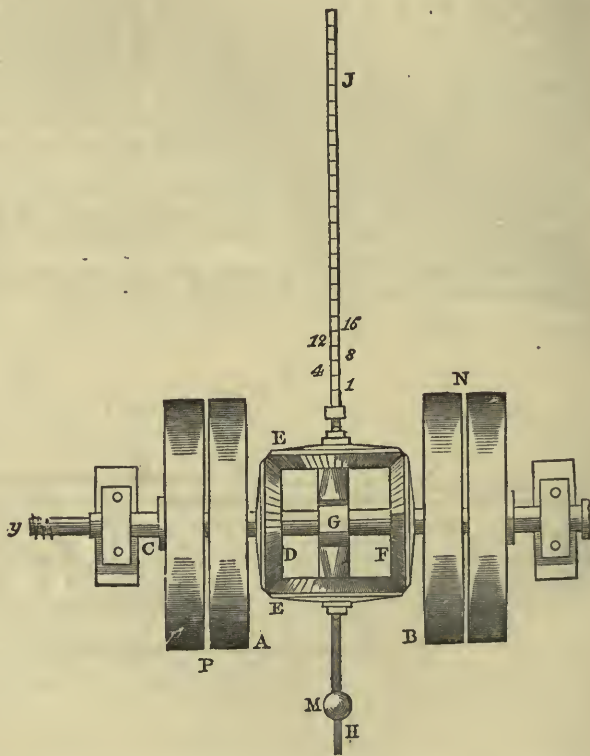
Description.—A is a pulley, Fig. 1159, which receives the power from the driving-pulley, which is transmitted through the geers C D and E to the pulley B, thence to the driving-machine. The pulleys are out side of the frame, the geers C E inside of the frame, and supported by it; the intermediate geer D hangs in a stirrup, supported by the beam F, which is a steelyard, whose fulcrum is *f*. But it must be remarked, that the strain on the centre of the intermediate geer (since the pilot line of the geer on one side is the point of application of the power and on the opposite side is the fulcrum) is double the power transmitted by the machine. G is a cylinder filled with water, in which a piston, fitting loosely, is attached to the beam F, and is used as a regulator to prevent sudden oscillations in the beam, which invariably occur in such machines.

DYNAMOMETER. Figs. 1160 and 1161 are two views of a dynamometer constructed on the principle of what is called the "differential-box," and consists of two pair of belt-pulleys A A, B B, mounted on the shaft C C: one of these pulleys on each side is loose, while the other is fast. The fast pulley on the side A A, and the bevel-wheel D, are both fastened to the shaft C C. The bevel-wheel F is fastened on a small tube connected with the pulley B. The wheels E E are connected by G, which is constructed so as to revolve round the shaft C C. To apply this simple machine, a belt from a drum on the main driving-shaft is brought to the pulleys A A, whilst another belt is carried from the pulleys B B, to the machine or machinery, the weight of which is to be ascertained. And it is plain, that if the pulleys A A, and the wheel D, are once put in motion, the wheels E E will also revolve on their axis, and at the same time the connection-shaft G will revolve round the shaft C C, thus leaving the wheel F and the pulleys B B, standing still; but, if the wheels E E are kept in their present horizontal position, and prevented from revolving round the shaft C C, it is equally obvious, that the wheel F and the pulleys B B will then be moved at the same speed as the wheel D and the pulleys A A; hence the weight required to keep the wheels E E in their present position, is equal to the weight required to move the pulleys B B. The weight thus required, is found by means of the lever H J. The arm H is attached to the centre of the wheels E E, by the straps *a a*, Fig. 1160. The arm J is divided upon the principle of the Roman steelyard. The weight M is merely intended to balance the arm J, and being

1160.



1161.



fastened with a set-screw, can easily be shifted on the arm H, as may be found requisite. Therefore, when the wheels E E are kept in their present position by means of the lever J H, it is evident that a weight of 20 lbs. acting upon the pulleys A A at P, will balance another of the same weight at N, of the pulleys B B. Now the distance from the centre of the shaft C C to the division on the lever J marked 1, is equal to the radius of the belt-pulleys; hence a weight of 20 lbs. at 1 will counterbalance the same weight at P,—that is, making no allowance for friction, the amount of which is ascertained by the additional weight required to balance the given weight at P; and having once ascertained the proper allowance for friction, the machine is put in motion by shifting both belts on to the fast pulleys, and moving the balance weight along the lever J from 1 to 4, 8, 12, or to whatever number will balance the wheels E E; and the weight thus indicated on J, is the weight required to move the machine or machines, from which deduct the allowance for friction. A worm at *y* on the end of the shaft C C, works into a wheel with an index and pointer, in order to show the speed at which the machine is driven, and also to determine the difference of the weight of any machine at different speeds. From the above description it is presumed that the principle upon which this dynamometer is constructed, as well as the mode of applying it, will be easily understood.

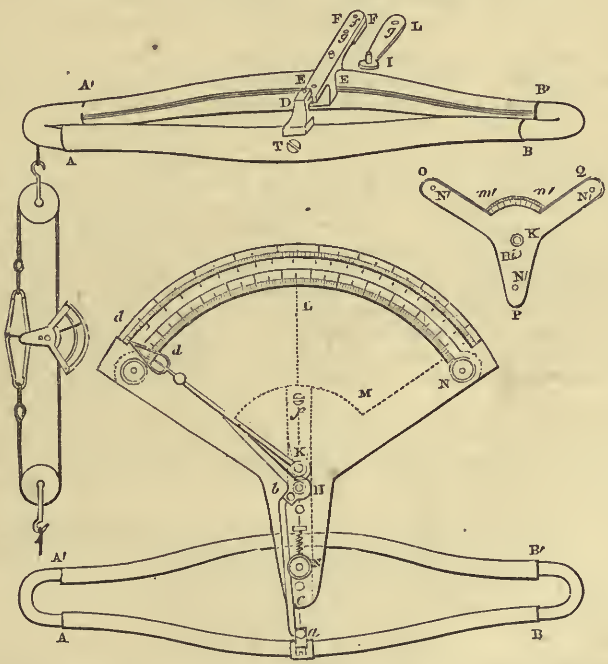
An improvement has been made on this machine by J. B. Francis, Esq., of Lowell, by which the

power is transmitted to and from the dynamometer in the same line; thus, instead of the pulleys B B a geer is employed, which works in an equal geer fixed to the end of an extra shaft parallel to C C, on the opposite end of which, and on a line with A A, is a pulley of the same size as A A, from which power is transmitted to the machine to be driven. The beam is balanced without the use of a moveable weight M, and to this end a regulating pump is attached, as in Brown's machine. A clock is driven by an endless-screw on the extra shaft, which registers the revolutions of the shaft, and a bell strikes at every 50th revolution. The beam J is so graduated, that the power used, or weight raised 1 foot high per second, is obtained directly, by dividing the weight as shown on the beam, by the number of seconds occupied by the shaft in making 50 revolutions. The friction of the machine was taken by the use of Prony's friction break, placed on the extra pulley, and was ascertained exactly by a course of experiments, on different speeds and weights.

DYNAMOMETER. *Regnier's Dynamometer* resembles a common graphometer, the principal part of which instrument is a steel spring bent in the form of an ellipsis; it should be properly tempered, and well welded, and covered with leather, to prevent injury to the hands when used. This spring is represented by A A′, B B′, formed by two equal plates united at the ends by rounded half-rings. The dimensions of this spring vary according to the tension required, or the weight to which it is applied.

The dynamometer used to ascertain human strength weighs little more than two pounds, and serves to measure a thousand times that weight; its total length is about 12 or 13 inches, and its greatest breadth, as measured in the middle of the two arcs, is 2·2 inches, and the least breadth at the extremity of these arcs is $\frac{3}{4}$ of an inch. The thickness of the arcs at their centres is nearly 2 inches, and its height, which decreases from the centre towards its ends, from $\frac{1}{10}$ to $\frac{4}{10}$ of an inch; the chords of the two arcs are 6·4 inches. This length, added to that of the two demi-rings, gives for the total length of the dynamometer 12 or 13 inches. The distance between the parallel chords is about $\frac{3}{4}$ of an inch, and the perpendicular of the arcs are each $\frac{7}{10}$ of an inch, giving about 2·2 inches for the total distance between the centres of the arcs.

1162.



There are two methods of stretching the spring, by pressing it in the direction of the perpendicular of the two arcs which form it, or by drawing it with the two rings at right angles to that perpendicular: these two limits of tension are indicated by two scales drawn on the same limb, called scales of pressure and tension: the first gives the pressure of weight from zero to 264 pounds avoirdupois. The greatest pressure brings the centres within 0·4 of an inch of each other, each perpendicular, which is 0·7 of an inch when there is no pressure, is reduced to 0·5 of an inch. The brass limb on which the scales are drawn is fixed on the centre of the arc A′ B′ of the spring, and the opposite arc A B carries a counterpoise *a b*, 3·1 inches long; the extremity *b* of this counterpoise acts on a small branch *b* H, 0·3 of an inch of a bent-lever, *b* H *c*, whose other branch H *c* is a needle, 2·4 inches long, from the centre H of rotation to the index *c*. Below this index is a small cylindrical thread, 0·1 of an inch, which is fixed to the needle H *c*, and serves as a foot when it turns on the centre H, parallel to the limb. This first needle by turning communicates a rotatory movement round the centre K to another needle K *d d′* which rolls on

the smooth portion of the screw K, and leans on the limb by a foot G furnished with a washer to reduce friction. This second needle has two indices d and d', to mark the pressure and traction; it is moved by the first needle H c; the divisions of the arcs described by the two indices are numbered in pounds, which indicate the weight brought by the needle to these divisions: as long as the spring is not stretched, the needle H c preserves its primitive position, and the needle K $d\,d'$ of the scales remains on the divisions to which it is drawn by the tension of the spring; whence it is seen that the system of two needles gives us the power of preserving the measure of a tension, when the force which produced this tension no longer acts. The greatest arc which the needle H c can describe is determined by the course of the counterpoise $a\,b$, which is 0·39 of an inch. The points b and c of the bent-lever G H c describe arcs of the same number of degrees: with regard to the positions of the two needles H c, K $d\,d'$ to the right line H K L of their centres, the angle c K L, which the second needle makes with this right line, is equal to the angle c H L of the first with the same right line, increased by the vertical angle H c K of the two needles, for in the triangle H c K, whose sides H c and H K are constant, the angle c K H is the supplement of the angle c K L, and of the sum of the two angles c K H and H c K. The distance H K of the centres H and K is about 0·46 of an inch, and it results that the total arc described by the needle K $d\,d'$ is nearly one-third of the circumference.

To preserve from injury the system of these three pieces, viz., the counterpiece $a\,b$, the bent-lever b H c, and the needle with two indices K $d\,d'$, the limb is covered by a plate N N N, which rests on the three pillars, 0·39 of an inch high. If the axis of rotation of the bent-lever were prolonged, it would meet this plate in the point H′, the centre of the arc of a circle $m'\,m''$ which terminates it, and whose radius is equal to the length of the needle H c. The divisions of the arc $m'\,m''$ are figured, and the figures indicate the same tensions as those on the scale of traction.

The dynamometer just described indicates on the scale of traction a tension of a ton weight, which is greater than the most powerful effort of a horse, but nevertheless too small to measure the ordinary effort of a power applied to a screw.

M. Regnier constructed a dynamometer on the same principles, which measures a traction of 6,600 lbs.: the spring was of the same power and length as the old one, but the two arcs or plates of which it was composed were longer, thicker, and further apart in their centres; their distance from each other was 4·5 inches; by the greatest traction it was only diminished 0·4 of an inch; these arcs had in the middle a breadth of 1·8 inches, and a thickness of 0·2 of an inch; the total weight of the instrument was 5½ lbs.

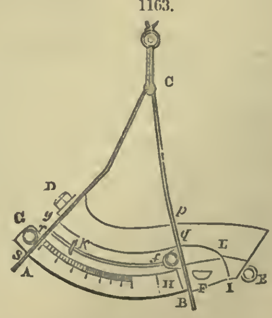
By placing the machine between the two ends of a cord passing over two or more pulleys, the ratio of the force which separates the extreme pulleys to the tension of the cord will be known, and by this disposition we can measure a traction much more considerable than that which is indicated by the scale of the dynamometer. Fig. 1162 shows the arrangement with two pulleys.

Details of the Construction of the Dynamometer.—Two supports D D′ of steel, are adjusted solidly on the two opposite branches of the spring in the direction of the perpendicular of the axis. The first support D, cut in a fork, carries a screw on which the extremity a of the counterpoise $a\,b$ rolls; it is about 1·4 inches high, and 0·59 wide; it is retained on the centre of the arc A B by a strong screw, whose head is marked T on the convex part of the arc. The second support D is also retained by a screw, the extremity of which, t, is seen on the concave part of the arc A′ B′; the upper face E E of this support is about 4 inches long: on the opposite face E F, which is of the same length, is a brass plate I L, fixed by a single screw g, which is level with E F in g: the plate, hardened to make a spring, carries at its extremity a pivot I, which passes through the support and the limb; this pivot, like that of a compass-needle, serves as a centre to the bent-lever b H c: the limb is applied to the face E F of the support D′, and is fixed there by two screws $e\,f$. The plate I L being a spring, the pivot I yields to a pressure of the counterpoise, and prevents any rupture of the mechanism which turns the needles or the scales.

The covering plate O P Q is voided at K′ in a small circle of a diameter nearly equal to that of the head of the screw K, round which the needle K $d\,d$ works, with a slight friction on the limb: if this friction be too slight, a turn-screw which passes through the circular opening K′ will tighten the pressure. The lower pivot of the bent-lever b H c rolls on the pin I′; its upper pivot rolls on the side H′, which is riveted to the covering plate O P Q.

Spring-Balance and Eprouvette. The spring-balance most used in commerce is formed of two steel branches A C, C B, bent at an angle of 45°; each of the arcs D $p\,q$ E, I H G, is fixed to one of the branches and traverses the other. By drawing the rings E G, which terminate the arcs in opposite directions, we bring the branch A C near B C; a circular scale figured from 5 to 40 indicates the respective positions of these two branches. The branch A C pushes before it a small cursor k of card or leather, which slides easily on the metalic wire $f\,g$, attached to the branch C B of the balance. To graduate the scale, suspend the balance by a ring E fixed to the branch A C, and attach weights to the ring G, which is at the extremity of the scale. The numbers on the scale indicate the tension of the spring.

1163.



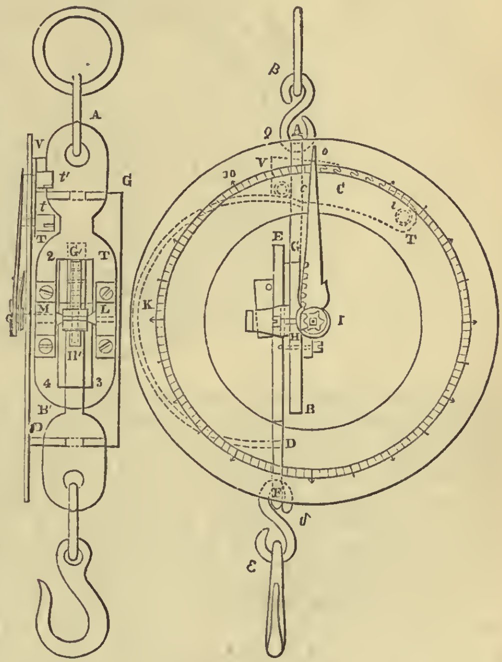
Regnier has made an excellent instrument of this spring-balance for trying the strength of powder. The length of the branches A C and C B is about 4·8 inches, and their breadth about an inch; a small brass cannon, whose breech H is on the branch C B of the balance, and whose mouth I is closed by the fuse I L of the obturation D I L E fixed on the other branch A C of the balance, contains a given weight of the powder to be tried; it is primed by a little powder put in the pan F: the powder within the cannon is fired and drives it away; after the ignition the two branches

of the balance approach, and the cursor k indicates on the scale the tension of the spring at the moment of the explosion. The iron D E, and the brass arc G H on which the scale is drawn, pass through openings $p\ q$, $r\ s$ made in the middle of the plates C B and C A.

A dynamometer for measuring animal force was invented by Mr. Graham, and afterwards improved by Desaguliers, but it was found to be inconvenient for the purpose, as it was made of wood. Leroy afterwards formed one in a metal tube 10 or 12 inches in length, with a spring within it placed vertically on a stand. This, however, was not found so useful as Regnier's, where the sides of the spring are made to approach each other, and move an index, which marks the degree of approximation on a semicircular scale: a man can ascertain by it the mean force he exerts with either hand, or with both together; it was with this kind of dynamometer that M. Quetelet, of Brussels, made his experiments upon the strength of men of different statures and ages.

Another kind of Spring-Balance.—The spring of this balance is bent in a curve C K D, terminated by two braces, C B, D E, one of which supports the pinion I, and the other a rack D E G H, of which the toothed portion G H catches the pinion I. This pinion and the needle which marks the tension of the spring turn on the same axis.

1164.



The face is a circle whose centre is on the axis of the pinion I, and is fixed by two screws t and t', on the plane T V, which is soldered to the upper brace A B, which carries the pinion. To graduate the scale, suspend the balance by the ring A, and attach known weights to F by the hook $d\ c$. The rack G H will work the pinion I, and the needle fixed on the axis of this pinion takes up successively the positions figured from 0 to 100; these numbers express the force of tension on the spring in pounds. The index of the needle describes about $\frac{5}{8}$ of the inch as the maximum tension of the spring, or for the greatest distance between the extremities C and D of the spring, which is about 1·1 inch.

The plane of the balance being supposed vertical, as in the projection, on another vertical plane passing through the axis of the pinion; the face of the brace A B, perpendicular to the plane of the limb, is drawn parallel to itself in A′ B′; we see on this face in the parallelogram 1 2 3 4, the projection of an opening made in the thickness of the brace A B, to make way for the toothed part G H of the rack; the breadth, 1 2 or 3 4, of this opening is 4 inches; L M is the projection of the axis of the pinion I; the spring C K D is projected in C D; the plane on which the face is screwed has for its projection T V. The spring is 0·11 of an inch thick, and 1·2 inches broad. To render this balance more convenient, a needle is added, which turns freely on the face round the axis of the pinion I, and may be employed as the dynamometer; it is even preferable for measuring the ordinary strength of men.

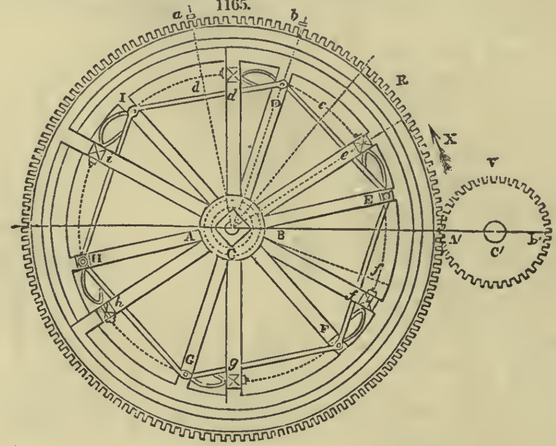
Of the Dynamometric Machine, and the Measurement of the Tangential Force of an Axletree.—Let A B, Fig. 1165, be the section of an axle moved by water or any other power; an unknown but constant resistance acts tangentially to this axle, and we require to measure it. To resolve this question, suppose we fix on the axle A B of a wheel D E F G H, of any number of rays C D, C E, C F, &c.; this wheel turns with the axle. Another wheel having the same number of spokes, C d, C e, C f, turns freely on the same axle; springs D d, E e are attached to the couples of the spokes, C D, C d, C E, C e of the two wheels, so that the points of attachment D and d of the extremities of the springs are in a plane perpendicular to the axis of rotation C of the axle A B, and at an equal distance from this axle.

Having disposed the power or mover so that it shall turn the wheel freely in the direction of the arrow X, it is evident that the extremities $d\,e$, $f\,g$ of the springs fixed to this wheel, would swerve from the points of attachment D E F, &c.; that the equal angles D c d, F c e, E c f, &c., whose sides pass through the extremity of the springs, considered in their primitive position, would become other equal angles D c d, E c e, E c f, &c., and all the other springs would be stretched, if not equally, at least at the same angle: when the total tension of the springs is equivalent to the resistance applied tangentially to the axle, the system of the two wheels will turn on the axis A B as one and the same wheel. Now suppose that the axis turns, and that we can measure one of the angles D c d', at which all the springs are stretched, we shall have in the triangle D C d' the angle C, the equal sides C D, C d, and consequently the perpendicular let fall from the centre C on the side D d, or the radius of the circle to which the force which stretches the spring is tangential. We may, besides, observe the number of turns of an axis in a given time, whence we may deduce the velocity of the point at which the force

that stretches each spring is applied. Multiply this velocity by the sum of the tension of the springs the product will be the dynamic effect of an axis in a unity of time, for example 1″.

To measure the angle D c d, which moves in a plane perpendicular to the axis of rotation C of the axis A B, we fix on the lines C d, C D, the middle of the radii, two small hammers a b, coupled by a spring D d', which each moves in a plane perpendicular to the axis of rotation C, and at equal or unequal distances from this axis, but greater than the radii of the wheels. These hammers strike two bells placed beyond on circles described through a and b. This being arranged, we can with a seconds watch measure the time which elapses between the two consecutive sounds resulting from the blow of each of the hammers on the bells, and knowing besides the time of the entire revolution of the hammers, these two portions of time will be in the ratio of the arc which measures the angle of the right lines passing through the extremity of each spring to the entire circumference. This angle being known, we can easily measure the weight which stretches each spring at a known angle, and the sum of these weights will be the total tension of the dynamometric machine.

1165.



By this description it will be seen that simple springs without needles or scales, whose force of tension for the same lengthening may be sensibly unequal, give exactly the measurement of a tangential force applied to axes: by taking springs capable only of a tension of a ton, we may place eight on a circle of 39·37 inches radius, and eight others on a concentric circle of 8 decimetres, supposing the axle makes four turns per minute; the dynamometric machine will show, on this hypothesis, that the dynamic effect produced by a force applied to an axle is nearly equivalent to that obtained from 80 horses.

Another dynamometer deserves to be mentioned: a vessel containing water should have a cylinder, made of some heavier substance than the water, suspended in it by a rope passing over a pulley: when the upper surface of the cylinder is on a level with the surface of the water, the weight of the cylinder, or the force which it exerts upon the rope, will be equal to the absolute weight of the cylinder in air diminished by the weight of a quantity of water of the same magnitude as the cylinder: a horse or a man pulling at the rope to raise the cylinder above the fluid surface, the weight of the cylinder will gradually increase; and if the magnitude and specific gravity of the cylinder are duly adjusted to the force, there will be a particular position of the cylinder at which its weight will exactly balance that applied. The forces in equilibrio, or those required to be measured, will be equal to the absolute weight of the cylinder, diminished by the weight of a quantity of water equal to the magnitude of the immersed part of the cylinder: a scale attached may be so set out, that it will accurately measure the force applied, and the cylinder can be increased to any length by diminishing its diameter, so that a very lengthened division may be adopted.

ECCENTRICS. The term *eccentric* is applied in general to all such curves as are composed of points situated at unequal distances from a central point or axis. The ellipse, the curve called the *heart*, and even the circle itself, when supposed to be fixed upon an axis which does not pass through its centre, are examples of eccentric curves.

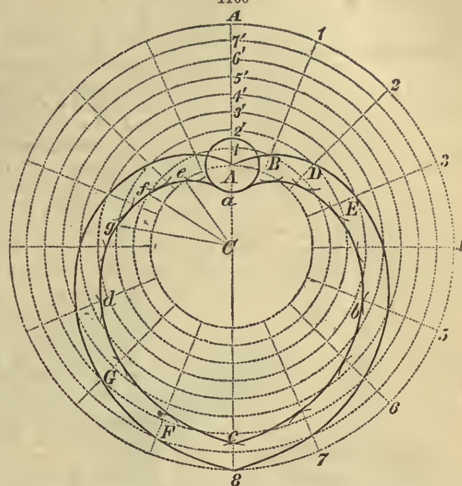
The object of such curves, which are of frequent occurrence in machinery, is to convert a rotary into an alternating rectilinear motion; and their forms admit of an infinite variety, according to the nature of the motion desired to be imparted. Examples of their application occur in many arrangements of pumps, presses, valves of steam-engines, spinning and weaving-machines, &c.

Fig. 1166 illustrates the distribution of the eccentrical symmetrical curve called the heart, which is such as, when revolving with a uniform motion on its axis, to communicate to a moveable point A, an uniform rectilinear motion of ascent and descent.

Let C be the axis or centre of rotation upon which the eccentric is fixed, and which is supposed to revolve uniformly; and let A A′ be the distance which the point A is required to traverse during a half revolution of the eccentric. From the centre C, with radii respectively equal to C A and C A′, describe two circles; divide the greatest into any number of equal parts (say 16), and draw through these points of division the radii C 1, C 2, C 3, &c. Then divide the line A A′ into the same num-

ber of equal parts as are contained in the semicircle (that is, into 8 in the example now before us), and through all the points 1′, 2′, 3′, &c., draw circles concentric with the former; the points of their intersection B, C, E, &c., with the respective radii, C 1, C 2, C 3, &c., are points in the curve required, its vertex being at the point 8.

1166



It will now be obvious that when the axis, in its angular motion, shall have passed through one division, in other words, when the radius C 1 coincides with C A′, the point A, being urged upwards by the curvature of the revolving body on which it rests, will have taken the position indicated by 1′; and further, when the succeeding radius C 2 shall have assumed the same position, the point A will have been raised to 2′, and so on till it arrives at A′, after a half revolution of the eccentric. The remaining half A G F 8 of the eccentric, being exactly symmetrical with the other, will enable the point A to descend precisely in the same manner as it is elevated. It is thus manifest that this curve is fitted to impress a uniform motion upon the point A itself, but in practice a small friction roller is usually interposed between the surface of the eccentric and the piece which is to be actuated by it. Accordingly, the point A is to be taken as the centre of this roller, and the curve whose construction we have just explained is replaced by another similar to, and equidistant from it, which is drawn tangentially to arcs of circles described from the various points in the primary curve with the radius of the roller. This second curve is manifestly endowed with the same properties as the other; for, supposing the point *e*, for example, to coincide with A, if we cause the axis to revolve through a distance equal to one of the divisions, the point *f*, which is the intersection of the curve with the circle whose radius is C 1′, will then obviously have assumed the position 1′; at the next portion of the revolution, the point *g* (which is such that the angle *f* C *g* is equal to *e* C *f*) will have arrived at 2′, and so on. Thus it is plain that the point *a* will be elevated and depressed uniformly by means of the second curve, in the same manner as that denoted by A is actuated by the first.

It is obvious that the movable point A must, in actual working, be held in contact with the surface of the eccentric; this is generally accomplished by the action of a weight or of a spring; but in forms similar to fig. 1166, in which all the diameters, as A 8, B F, D G, &c., are equal, two friction-rollers A 8 connected and placed diametrically opposite each other may be used, which will be thus alternately and similarly impelled; in many cases an eccentric groove is cut, and the friction-roller or point A, is made to slide in this groove.

ELECTRICITY. All substances are susceptible in a greater or less degree of electrical excitation, but according to their readiness to evince electric properties by friction, they are classed as electric or non-electric. Electric substances have not only the property of electrical excitation, but also the power of confining, or imprisoning, as it were, the communicated electricity upon other bodies, in which it could not under the same circumstances be so excited; while on the other hand, the non-electric substances allow the electricity to pass off. Non-electric substances, therefore, have been called *conductors*, and *electric* substances, *non-conductors* or *insulators*. These expressions are merely relative, yet the difference in conducting powers in certain bodies is enormous; that of iron, for instance, being estimated at 400 000,000 times greater than that of water.

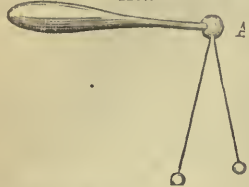
Excitation of Electricity by the Mechanical Movements of Bodies.

* Various names have been applied to denote the different modes of producing electrical excitation. When one body is rubbed by another, as in the case of the common frictional electrical machine, this peculiar mode of excitation has been termed "Frictional," and "Mechanical," and hence the term "frictional electricity" and "mechanical electricity" has originated. The excitation developed by means of heat, has been denoted "Thermo-electricity;" that developed by means of magnets, "Magneto-electricity;" that by means of the chemical decomposition of zinc by acids in the battery cell, "Galvanic" and "Chemical" electricity. The excitation developed by the organs of certain fishes, has been termed "Animal" electricity. These several distinctive names appear to have been introduced into popular use for the convenience of arranging classes of facts of different modes of exciting electrical action, rather than for establishing any discrimination in the essential nature of the electricity excited. Indeed, Professor Faraday instituted a course of experiments for the express purpose of proving that there is no actual difference in the nature of electricity, however excited, and that all these kinds of "electricities" are identical. Considering all electric excitation to be simply the propagation of mechanical action through the medium of electric matter, and that impulses of mechanical force are all identical in their nature, however excited, and however propagated, the preceding result, verified by Faraday, might be theoretically anticipated. The presence of electric matter in motion, or in an excited state, is tested by its propagation of motion to some kind of freely movable and palpable portions of matter. In the

* Allen's Philosophy of the Mechanics of Nature.

construction of all kinds of electroscopes, the principal study has been to arrange the lightest, or most flexible portions of matter, in the most freely movable positions near each other. Although feathers, pieces of threads, and of straws, may serve to detect by their movements the propagation of electric action, yet convenience has been consulted in using other substances systematically arranged in the form of instruments. One of the simplest kind of electroscopic instruments is constructed of a couple of

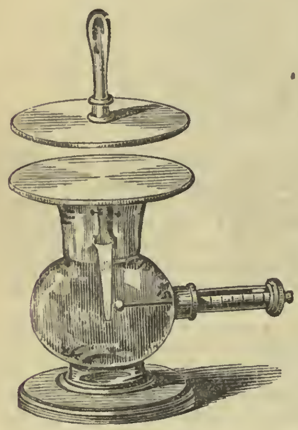
1167.



balls of the size of a pea, made of the pith of alder or of a cornstalk, suspended by very fine silver wires, or threads coated with black lead, and suspended from a metallic knob A, attached to a glass handle to insulate it, as shown in the figure. On bringing the knob A into contact with an excited body, the balls will become divergent as seen in the figure; and if a body be not electrically excited, the balls will continue drooping in contact with each other. The different degrees or extent of their divergency will of course indicate the degree of intensity of the electro-dynamic action. This fact of a reciprocal separation or repulsion of two bodies, is assumed to be a test of electrical excitation.

Hare's Electroscope.—Fig. 1168. By inserting a wire M, with a brass knob affixed to the end of it, which may be approximated by means of a screw cut upon its circumference to within a very minute distance of a single strip of gold leaf. The intensity of the propagation of the electro-dynamic action

1168



through a space of air being found to decrease in the inverse ratio of the squares of the increased distances, this instrument becomes thus exceedingly sensitive to the slightest disturbances of electrical matter in the gold leaves propagated from the metallic cap, which is made of zinc. By means of this simple instrument, one of the most important facts in the whole science of electro-dynamics may be experimentally demonstrated by bringing into contact with the plate various kinds of metals, as the plate insulated by a glass handle. A disturbance of the natural electrostatic condition of the plate and of the gold leaves suspended therefrom, is producible by the simple approximation and contact of various bodies with the plate; the sifting of various pulverized substances thereon being sufficient to produce the movement of the gold leaf. Both of these metallic plates may be separately examined by the test of the contact with other electroscopes composed of pith balls or flexible gold leaves, and no signs of electricity will be discoverable. Now place the plate of copper on the plate of zinc, which is called the *cap of the electroscope*, and hold one hand in contact with M, which is to be screwed up until the ball at the end of it is brought close to the tip end of the pendent strip of gold leaf; and with the other hand, touch the copper plate, and then lift it by the glass handle from the zinc. At the instant the separation is effected, the gold leaf will be seen to strike the ball, if the latter be previously brought to within the distance of $\frac{1}{20}$th of an inch from the former. This instrument serves the purpose of a delicate *electrometer* to measure very minute degrees of intensities of electrical action.

To demonstrate that an *artificially excited* body will develop electrical excitation in another unexcited body with which it may be brought into contact, Volta invented a very simple kind of electrical machine, which he denominated *The Electrophorus.*—The name of this electrical apparatus is derived from the Greek words signifying "*Producer of Electricity.*"

The *electrophorus* consists simply of a cake of sealing-wax, which material is selected as being a readily-excitable substance. A more tough and useful compound is commonly used, made by melting

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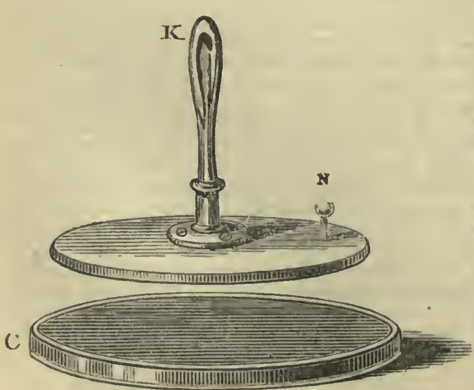


together equal parts of pitch and resin, combined with a little linseed oil. This composition, whilst in a melted state, is poured into a flat circular tin dish, having a rim of about half an inch in height, as shown at C. A round metallic plate D, adapted to the size of this cake of resinous matter, is affixed to the insulating glass handle K, by which the plate of metal may be alternately lifted from the cake of resin, and again brought into contact therewith.

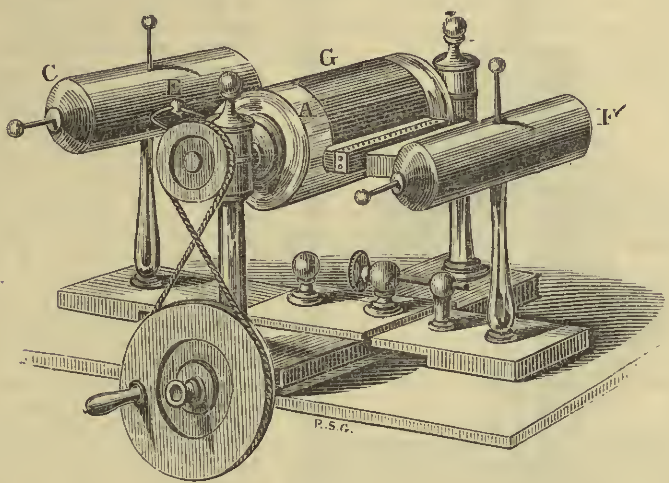
Whenever it is desirable artificially to propagate electro-dynamic action from the cake of resin to some adjacent body, the circular plate of metal is taken by the tip of the glass handle, and brought into contact with the cake of resin, and at the same time the finger is brought to touch the plate. Then the finger is to be withdrawn, and the plate removed by holding the tip of the glass handle.

The electrophorus is used practically for producing instantaneous light, by causing an electric spark, always excitable in an instant from

the plate on being lifted from the cake of resin, to kindle a jet of hydrogen gas artificially arranged to issue from a small apparatus, containing a lump of zinc in acidulated water.

The mechanical *pressure* of bodies, as well as friction and contact, propagates electro-dynamic action. Elastic India-rubber or caoutchouc, develops extraordinary electric excitation by sudden compression Sparks issue in vivid coruscations to a distance of several inches from between the rollers used for compressing sheets of this material in the process of incorporating it into manufactures of cloth. In certain processes of calico printing, the India-rubber, dissolved in spirits of turpentine and alcohol, and mixed with ultra-marine blue, or other colored substances, is passed with great pressure between the engraved copper rollers and the cloth to be imprinted therewith. A torrent of sparks I have noticed to issue from the compressed India-rubber, too intense to be sustained by the knuckles, held near them, without absolute pain. Indeed, the process of printing with this material was finally suspended from the danger of burning up the building and machinery employed, the sparks having actually set fire to the composition of turpentine, alcohol and India-rubber, and caused the cloth in the machine to be burnt up.

1170



Frictional electrical machines were first constructed to be operated by the *successive approximations* or *contacts* of the parts of the revolving glass cylinder A, against the parts of a rubber attached to a hollow metallic cylinder F, mounted on a pillar of glass. This pillar is sustained on a sliding base-board at the bottom, capable of being moved by a screw towards the glass cylinder, to regulate the intensity of the pressure, and consequently of the friction of the rubber. The rubber is made of leather stuffed with horse hair to constitute an elastic cushion.

Another hollow metallic cylinder, termed a "prime conductor," is represented at E, furnished with a row of pointed wires facing the glass cylinder, designed to serve for collecting the electricity excited therefrom. To prevent the escape or propagation of the electro-dynamic action from the prime conductor, it is *insulated* by the intervention of a non-conducting glass pillar. A flap of silk G, is attached to the cushion, and is spread out over the top of the revolving cylinder, to suppress the dissipation of the electrical action by the reaction of the air, before it reaches the row of points at E.

A revolving movement may be imparted to the glass cylinder by the animal motive power of the human hand applied to turn the crank-handle attached to the pulley W. Into this pulley a grooved score is turned, adapted to receive the cord that extends from it to a similar groove in a pulley attached to the axis of the glass cylinder.

The conductor E has also been denominated the *positive* conductor, in contradistinction to the conducter attached to the rubber, which is denominated the *negative* conductor, the former being supposed to contain an accumulation, or "positive" excess of the fluid; and the latter supposed to have yielded up a portion of its natural share of electricity, and to be reduced to a "negative" state.

To augment the excitation, it is usual to apply to the rubbing surface of the cushion a compound of metals triturated with lard. One part, by weight, of tin, and two parts of zinc, are melted together, and mixed with six parts of mercury, which are to be well stirred together until solidified. The brittle compound is then pulverized in a mortar, and mixed with a sufficient quantity of lard to reduce it to the consistency of a paste.

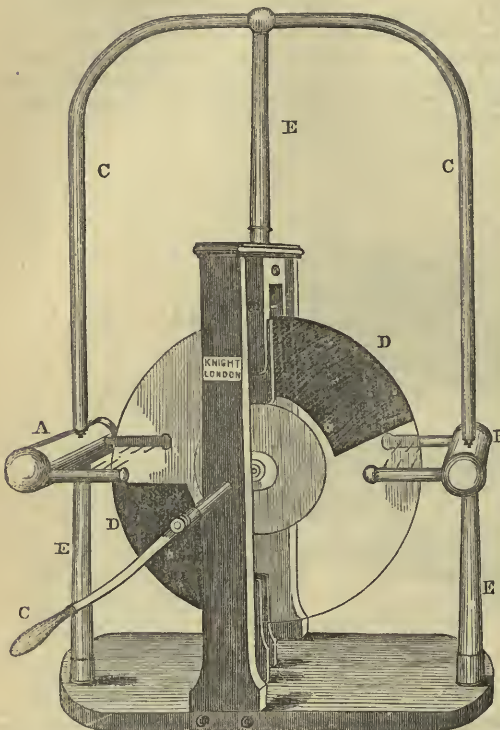
A superior improved *Plate Electrical Machine* has been introduced, which has superseded the use of the cylindrical machines, one of which is represented in fig. 1171.

The glass plate is caused to revolve by means of the crank handle C, attached to an axis passing through the plate, which is supported between two pillars. Attached to the inner sides of these pillars are four cushions, compressing the plate between them at the upper and lower portions of the disc, each having flaps of silk, D D, appended thereto. The intensity of the pressure of the cushions is reg-

ulated by screws. The two opposite conductors A B, are supported by two stout glass pillars E, E fixed at each end of the mahogany base-board, on which the other parts of the machine are mounted. The brass arch C C, is sustained at the centre and lower ends by the glass pillars E, E, E, and connects the two conductors A B.

The large electrical machine at the Polytechnic Institute, in London, has a plate of the diameter of 7½ feet, the sparks from the huge conductor of which, it is stated, "are nearly sufficient to fell a man to the floor."

1171



By scanning the details of the arrangement of the parts of the preceding machines, it is to be particularly noticed here, that the system kept in view throughout all the plans of their construction is simply confined to two distinct principles.

1st. To move one portion of matter near another, in order to disturb the natural state of rest of the electric matter existing in connection with both bodies.

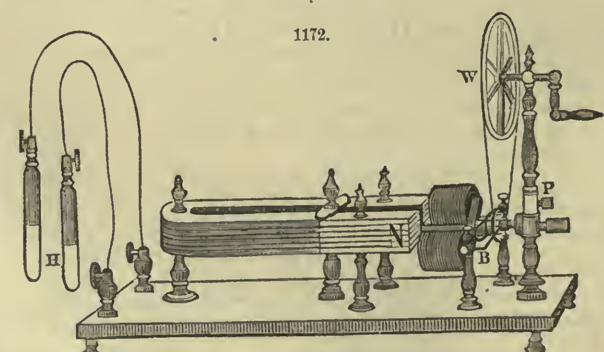
2d. To direct the consequent propagation of the electro-dynamic impulses in some one specific line of action, by means of interposed non-conducting substances, and of a continuous line of conducting substances, to concentrate them on a determinate point.

"*Magneto-Electricity*." The earliest account published of the first successful experiment in exciting electricity by the influence of magnets, appeared in April, 1832, in the "Annals of Philosophy," as communicated by Professor Faraday.

"If a wire, connected at both extremities with a galvanometer, be coiled in the form of a helix around a magnet, no current of electricity takes place in it. This is an experiment which has been made by various persons hundreds of times, in the hope of evolving electricity from magnetism; and, as in other cases in which the wishes of the experimenter and the facts are opposed to each other has given rise to very conflicting conclusions. But if the magnet be withdrawn, or introduced into such a helix, a current of electricity is produced *whilst the magnet is in motion*, and is rendered evident by the deflection of the galvanometer. If a single wire be passed along a magnetic pole, a current of electricity is induced through it, which can be rendered sensible. Whenever, also, a piece of metal is moved near a magnet, so as to intersect the magnetic curves, electricity is evolved, according to very simple laws."

Fig. 1172 represents a powerful magneto-electrical machine. The driving wheel W, may be turned either by the hand, or by a band moved by steam power or water power.

1172.



From the wheel W, a band is extended around a smaller wheel, or pulley to be turned thereby. The upper part of the pillar P, slides into the lower part, and admits of being fixed higher or lower by the binding screw P, so as to tighten the band as desired. An U magnet N, is fixed horizontally with its two poles as near to the ends of the armature B, as will allow the latter to revolve without touching

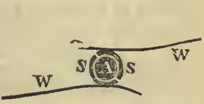
them. The armature is made of a piece of soft iron, bended twice at right angles to resemble also the shape of the letter U. Around each of its legs is wound a helix of fine wire coated with thread. This piece of iron with its environing coils of insulated wire, is fixed upon an axis extended from the pillar P to another pillar erected between the poles of the magnet. This axis is caused to revolve rapidly by the band from the multiplying wheel W.

Both of the arms of the revolving bar of iron are rendered magnetic for an instant, as they successively pass the two approximated poles of the permanent steel magnet N; and they cease for an instant to be magnetic on passing away from the influence of these two magnetic poles. The leg of the iron bar which approaches the N pole acquires the opposite south polarity, and the other, the opposite north polarity. The intensity of the excitation increases until the ends of the armature are exactly opposite to the ends of the poles of the steel magnet, and then diminishes to a minimum, when they stand crosswise to each other. By the continuance of the motion, each leg of the iron armature becomes oppositely excited on approaching the opposite pole.

These rapid transitions of magnetic excitations in the revolving bar of iron induces equally rapid transitions of excitation of the electric matter existing in connection with the coils of wire, wound around them both continuously. But it is manifest on inspecting the arrangement of these two coils of wire revolving about the axis, that their ends cannot remain connected with any stationary portion of the apparatus, as they would become broken off by the revolving movement. To overcome this difficulty, Dr. Page has invented a "*Self-acting Current Changer*."

In the figure, A represents a sectional view of the axis of the spindle carrying around the iron prongs with the environing wire coils. S, S, represent two semi-cylindrical plates of silver fitted to the axis A, but insulated therefrom by varnished silk or otherwise, and turning with the spindle. To each one of these semi-cylindrical pieces is soldered one of the two ends of the wire coiled about the iron prongs. In contact with these semi-cylindrical pieces, and gently pressing against them whilst they revolve beneath them, are the two elastic silver springs W, W, which remain at rest, being soldered permanently to the ends of the conducting wires that are designed for propagating the electric action to the bodies to be affected thereby. By this arrangement a continuous metallic contact is preserved between the ends of the wire coils revolving on the spindle, and the ends of the conducting wires leading to the two screw cups, shown at the opposite end of the base-board of the machine.

1173



By means of the mechanism of the revolving armature and coils, several thousand changes in the directions of propagation of the ebbing and refluent electric surges may be produced in a minute, when the wheel W is very rapidly turned by the crank handle, or preferably by steam or water power. The intensity of the ebbing and returning surges of electric action is correspondingly augmented with the rapidity of their movements toward and from the poles of the permanent magnet.

Although the directions of these ebbing and returning surges are reversed twice during each revolution, yet the connections of the two semi-cylindrical pieces are such as to turn all the ebbing surges in one direction, by one of the connecting pieces S, and all the refluent surges uniformly in an opposite direction through the opposite connecting piece.

It is necessary to adjust the contact of the springs with the semi-cylindrical pieces revolving with the spindle, so that the direction of the current in the coil may be reversed at the moment when the ends of the iron prong and coils have passed the poles of the permanent horseshoe magnet. By means of this arrangement, the effluent current of electric discharges are made always to escape in the direction through the binding-cup B, and the refluent current of shocks to return by the opposite binding-cup A; and thus by this regular changing of the connection with the ends of the wire environing the electro-magnetic iron prong, the *initial currents* of electricity are always directed to move separately in one direction, and the *terminal* currents in the opposite direction, in the same manner as occurs between the exciting rubber and main conductor of the electrical machine, and between the zinc and copper of a galvanic battery.

The uniform propagation of electro-dynamic action, in an uniform current produces less violent effects on the nerves and muscles of animal bodies than oppositely directed alternate surges of electric action. By adding to the magneto-electric machine the apparatus of a "contact breaker," designed to interrupt very rapidly a continuous action, it is capable of producing such a "torrent of shocks," when the machine is of large size, and the revolutions of it are rapidly accelerated, and such violent spasmodic contractions of the muscles of the hands, which grasp the handles, shown at H, in the preceding figure, as to prevent the tortured experimenter from dropping them, to relieve himself of the agony which he thus involuntarily endures. By means of this machine, impulses of mechanical force may be propagated through the medium of electric matter to put in motion light machinery, as that for striking a bell, with as much systematic regularity as the same impulses are commonly propagated through leather bands and iron shafts, for putting in motion mill machinery.

These magneto-electric machines excite electric currents which resemble those of galvanic batteries, being sufficient to operate electric telegraphs, to decompose water, to deflagrate metals, to heat fine wires red hot, to fire gunpowder, and to precipitate gold and silver from their solutions.

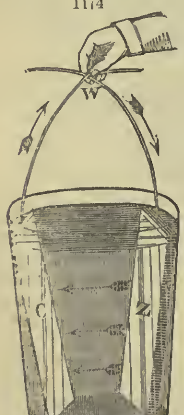
Mr. Shaw gives the following account of a powerful magneto-electric machine constructed by Mr. Woolrich, and used in the workshops of Birmingham for the practical operations of electro-plating and gilding. The magnets are made to revolve by the motive power of the steam engines which impel the other machinery operated in these workshops. He states, "that although the first cost of the magneto-electric machine is certainly greater than that of the galvanic apparatus necessary to produce the same amount of power, yet the expenses of working it are incomparably less, being limited to the cost of a trifling motive power of a steam engine or water-wheel. The economy of the magnetic machine for constant use must eventually gain for it a preference to the voltaic battery, where metal is to be depos-

ited on a business scale. All the wear and tear of these machines is, of course, limited to the friction between the axis and its bearings, and to that between the contact breaker and springs."

The expense of the consumption of the materials of acids and metals is very considerable in ordinary galvanic batteries. Thus, as illustrated by Mr. Shaw, "in depositing zinc, as in zincing or galvanizing the surface of iron, supposing two cells, arranged as an intensity battery, to be employed, the quantity of zinc deposited would be just one half of that decomposed and consumed in the battery, and very nearly the same proportion would obtain in the case of copper. Hence, the expense of this mode of plating or depositing metals, as compared with the value of metals deposited, is very great." By the use of the magnetic machine, on the contrary, the expense of depositing is limited to the trifling cost of the motive power required to produce the rotation of the armatures of the apparatus. So uniform is the current of electricity excited by this apparatus, and so regular is the process of the deposition carried on by means of it, that the mill governor, or regulator of the steam engine, serves actually to adjust it with such precision. that in a large establishment in Birmingham, where this process of electro-plating is extensively carried on, the quantity of metal deposited as a coating is estimated by the time during which the machine is worked. "Repeated weighings having demonstrated that the relation between the time of working and the quantity of deposited metal is sufficiently accurate." From 300 to 400 ounces of silver per week have been deposited from sulphite solutions of this precious metal, by a magneto-electric machine, described by Mr. Shaw, when the armatures were caused to make 650 revolutions per minute. In this magneto-electric machine, there are 8 armatures and coils, each of which become magnetic and cease to be magnetic four times in passing between the poles of 4 fixed permanent horseshoe magnets; and as the drum that carries them makes 650 revolutions per minute, there are, consequently, 20,800 changes per minute, from an unmagnetic to a magnetic state, induced in the 8 soft iron armatures; and an equal number of times per minute is a portion of the electricity naturally existing in connection with the wire coils expelled and returned. Thus 20,800 electric discharges per minute are turned by the *pole changer* to flow off in one uniform direction along the conducting wire, to exert their electro-mechanical action, like the regular current of a galvanic battery. During the most prolonged periods of the constant use of these magneto-electric machines, it is stated by Mr. Shaw that no appreciable diminution of their power has taken place, and no expense or delay is necessary to maintain them in good working order, such as is necessary whenever galvanic batteries are employed. The use of this magneto-electric machine in the art of Electro-Plating has been patented in England by J. P. Woolrich.

Galvanic Battery. When a piece of zinc is dropped into a vessel containing acidulated water, bubbles of gas are seen to issue from the metal, and the electro-dynamic impulses are propagated therefrom in every direction. By these counterbalanced opposite directions, the impulses neutralize each other's actions and reactions. Consequently, no decided electro-dynamic action is perceptible. This experiment has been repeated thousands of times before the discovery of the galvanic battery arrangement, without developing electric excitation. But if a plate of copper or platinum, as at C, in the figure annexed, be placed oppo site to the zinc Z, the impulses are determined through the water to the atoms of the copper plate, in one common specific direction.

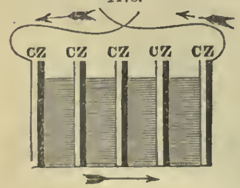
1174



One of the earliest modes of arrangement of the plates of galvanic batteries in a series was invented by Cruikshanks, and which, from its compactness, is still in use. The copper and zinc plates are soldered together in pairs, as it were back to back, each zinc plate being made to face an opposite copper plate as shown in fig. 1175.

Each plate is inserted in a groove, in a trough, and serves to form a water-tight partition, dividing the trough into an equal number of cells with the pairs of plates intervening between them. This kind of battery has been in very general use in lecture rooms.

1175.



Where a great number of pairs of plates are required to employ their combined powers of action, they are compactly arranged in battery form as shown in fig. 1176. The plates are suspended stationarily, and the troughs below, filled with acids, are raised up to submerge the plates therein by means of the two racks shown at each end of the apparatus. Small pinion wheels affixed to a shaft turned by the crank handle H, work into the teeth of these racks, and elevate or depress the troughs at the pleasure of the operator.

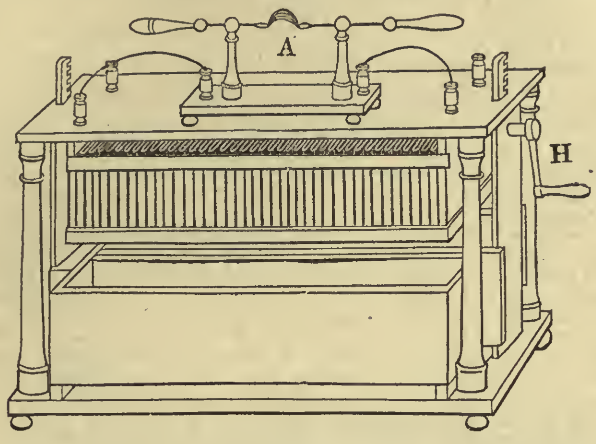
In the battery represented at fig. 1176, there are two distinct series of 50 pairs, each connected with two of the four cups on the table above the battery. By this arrangement the whole may be used as a single series of one hundred pairs, or as a battery of fifty pairs of double size, accordingly as the respective connections are formed with the binding cups. There being two separate troughs, only half of the battery may be used by removing one trough. These numerous pairs more particularly exhibit the phenomenon of electric flame between two separated points of the battery circuit as shown in the wood cut.

The usual mode of arrangement of batteries designed for the purpose of developing the phenomenon of heat, is in several pairs of very large sheets of zinc and copper, all the sheets of the former being connected by conducting wires, and all the sheets of the latter being similarly connected to represent the action of two single pairs.

Hare's Calorimotor—Fig. 1177. Dr. Hare devised a peculiar arrangement of the plates of a galvanic

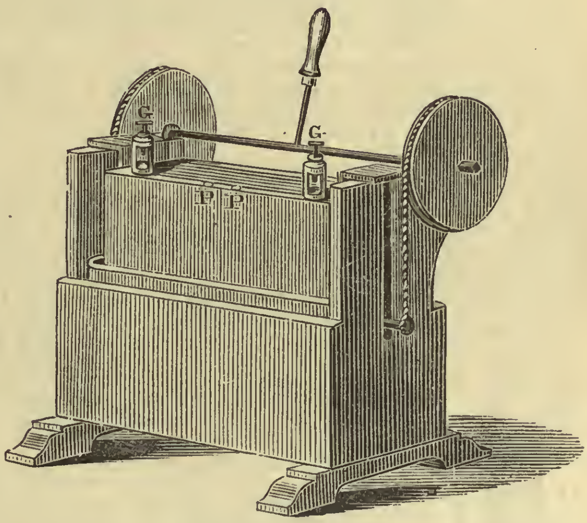
apparatus, in the year 1818, consisting of twenty-one plates of copper, communicating by a slip of metal, and twenty plates of zinc similarly connected, the plates of the one set being alternated between

1176.



those of the other, thus constituting only an equivalent to one pair, with one associated zinc surface and one associated copper surface, with the liquid interposed every where between them. Dr Hare remarks, "I ought to mention, that by means of a silver thimble, within which a minute piece of zinc was supported and insulated, Wollaston made an elementary battery capable of igniting a minute platinum wire. In enlarging the size of the galvanic apparatus, my course was diametrically opposite."

1177.



The figure represents the plan of Dr. Hare's instrument of four zinc and six copper plates. On pressing down the handle G, the pulleys are caused to revolve, lifting by the cord wound thereon the trough with the acid, whereby the plates are immersed therein.

For the purpose of producing an intense action in burning or deflagrating metals, &c., Dr. Hare constructed a convenient apparatus upon an enlarged plan, with 200 pairs of plates, each 14 inches by $7\frac{1}{2}$ inches, with the copper and zinc plates soldered together in a wooden trough on the "Cruikshank" plan, joined lengthwise, edge to edge to another trough, so that when the sides of one are vertical, those of the other must be horizontal. These troughs being united by a bar, serving as a pivot, when the bar is turned by a lever, the plates being placed in one of the troughs, and the acid in the other, by turning the trough containing the acid, it is caused to discharge its contents into the one containing the plates.

He made a very powerful battery by means of several sheets of zinc soldered together to form one continuous sheet, nearly fifty feet in length, with a similarly formed copper sheet of equal dimensions, wound together like a scroll, the two metals being kept separated by a rope of hair, wound intermediately between the sheets.

The calorific action of these galvanic batteries produced very surprising results in heating wires red hot and in deflagrating metals, &c.

Mr. Bain made the experiment of burying a large sheet of zinc in the moist earth of Hyde Park, London; and at another spot, more than a mile distant, he buried a sheet of copper of similar size. These two sheets he connected by a conducting wire, trained along the railings of the inclosure. With this simple apparatus he succeeded in producing the various phenomena usually attainable from a regular galvanic battery. "Without troubling himself with the preparation of acids and voltaic troughs,

he produced the excitation of regular electric currents, of sufficient intensity to be transmitted to distant places along connecting wires."

It is stated by Mr. Tylee, a chemist of Bath, England, that a battery composed of thirty pairs of zinc and copper plates, which he buried in the moist earth of a garden, formed a *terrestrial battery* admirably adapted for electro-plating processes; but the time required for completing the process was longer than with the acid battery.

In the practical operation of the original galvanic batteries, composed of plates of zinc immersed in acids, it was found that three distinct obstructing causes impeded the uniformity of the electrical excitation, viz: 1st, the accumulation of a coating of bubbles of hydrogen at the surface of the copper plate forming a non-conducting screen; 2d, the accumulation of the earthy matter of the oxide in the form of a crust or scale on the surface of the plates of zinc, serving as a coating to intercept the further access and grouping of the atoms of oxygen of the acids with those of the zinc; and 3d, the gradual exhaustion of the excess of atoms of oxygen, constituting the strength of the acids in their grouping with those of the zinc. The accumulation of bubbles on the surface of the plate, sometimes forms such a non-conducting coating as to prevent the plate from performing the designed functions.

Availing himself of the plan of arranging rows of pointed wires in electrical machines for determining more freely the propagation of electro-dynamic action, Mr. Smee contrived to impart to the surface of the plate a similar system of the sharp points of crystals of metals artificially formed thereon. He used plates of silver on which platinum on angular points of crystals are deposited. A wooden cross was used to sustain the pairs of metal plates, to each one of which screw-cups were soldered thereto, to insure contact. As the natural polarized condition of the atoms of copper plates is subject to be disturbed by the contact of acid solutions, and reduced to an oxide, like the metal zinc itself, in which cases counteracting neutralization of the electro-dynamic action of the battery is produced, Mr. Smee introduced the use of platinum as a substitute for copper.

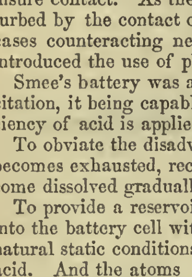
Smee's battery was a great improvement in the constancy of the development of effective electric excitation, it being capable of sustaining "active operation for six, eight, ten, or more days, when a sufficiency of acid is applied to it."

To obviate the disadvantage of a necessity of supplying fresh acid occasionally, as that in the cell becomes exhausted, recourse was had to the use of a quantity of acid crystals placed in the cells to become dissolved gradually, to furnish an uniform supply, for sustaining "constant batteries."

To provide a reservoir of acid, a quantity of the sulphate of copper or blue vitrol of commerce is put into the battery cell with the acid, in charging the battery. The atoms of zinc, in recoiling to their natural static conditions, become grouped with the atoms of the sulphur and oxygen of the sulphuric acid. And the atoms of oxygen previously united with those of the copper, become united with the atoms of the hydrogen set free by the decomposition of water, so as to reproduce water. No appearance of hydrogen, therefore, is perceptible in the cell of this kind of battery. The accumulation of bubbles of hydrogen is thus obviated.

The sulphate of copper battery, originally employed by De La Rue, is thus more effective than Smee's battery; but it is found that although the coating of bubbles of hydrogen is avoided, and a constant supply of acid is attained, yet the zinc becomes speedily coated with a scale of oxide, and with a coating of revived bright particles of copper. The only remedy for this difficulty is to withdraw the zinc plates and to scrape off the brown oxide and particles of copper adhering thereto. The crust of copper as well as that of oxide, accumulated on the plate of zinc, conspire to diminish the rapidity of the recoil of the zinc, and the consequent propagation of electro-dynamic reaction therefrom.

1178



The preceding defects have been, in a great measure, obviated by the ingenuity of Becquerel and Daniell, by protecting the zinc from the immediate access of the particles of copper and oxide. The zinc is inclosed within some porous substance, capable of intercepting the deposit of the obnoxious particles, as shown in the figure. In the sectional view given, C represents the outer copper vessel, serving both for containing the acid solution of sulphate of copper, and also to perform the function of a conductor. Within the copper cell is placed another smaller cell, made of porous earthenware, thus forming two distinct cells. The outer cell is used for containing the sulphate of copper, and the inner cell some other saline solution. The intervention of the porous vessel serves to keep the amalgamated zinc clean and bright for a longer time, and to impart to this battery a superior character as a "constant battery." The supply of sulphate of copper is furnished from a quantity contained in a muslin bag immersed therein, or from a deposit of it in the projecting nose of the outer copper vessel, as shown in the figure. Daniell recommends a mixture of eight parts of water and one of sulphuric acid, which is to be saturated with sulphate of copper, for the supply of the outer copper cell, the internal porous earthenware tube being filled with the same acid mixture without copper. The porous tubes should be well soaked in dilute sulphuric acid for an hour or two before being used; and after their removal from the battery, they should be repeatedly rinsed or soaked for some time in warm water to dissolve all the metallic salts from the pores; otherwise they will soon become broken, by the crystallizations of salts in the pores, like that of water crystallizing or freezing in bottles.

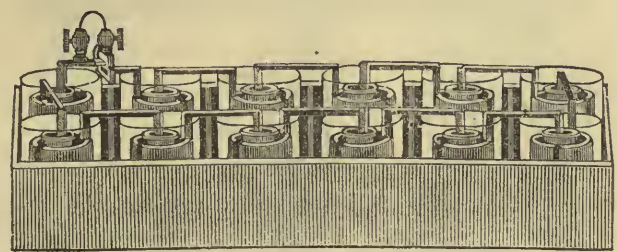
The zinc of commerce always contains more or less iron and other foreign substances, which develope minor circuits of counteracting currents, and essentially diminish the intensity of the excitation. To obviate this disadvantage, and also to keep the zinc plates clean and bright, Mr. Sturgeon originally applied a coating of mercury to the surface of the zinc. This coating serves also to prevent the wasteful recoil of the atoms of zinc to their natural polarized conditions whilst the battery is not in action by the connection of the battery circuit. This coating of mercury produces a result very different from

what might be theoretically anticipated; for, instead of protecting the zinc by preventing the immediate contact of the acid, it is found that the oxidated particles of zinc are withdrawn from beneath it, leaving the surface of the mercury clean and bright. The zinc is more rapidly decomposed by this arrangement, instead of becoming protected from further action of the acid, as occurs when a crust of oxide becomes deposited thereon. With this improvement the battery becomes far more "constant" than before, being capable of propagating a nearly unvarying electro-dynamic action during several days in succession, care being taken to provide an adequate supply of the crystals of blue vitriol, and to stir the solution in order to diffuse it equally throughout the external cell. For purposes requiring an uniform electro-dynamic action to be continuously sustained, as in the process of electro-plating metals, this form of battery is advantageous.

A still further improvement in the use of acids employed in battery cells, was made by Bunsen and Groves, by using nitric acid in contact with the platinum plate, contained in the porous earthenware vessel, shown in the preceding figure. Sulphuric acid, diluted with four or five parts of water, is poured into the outer glass vessel containing the zinc cylinder, which has a division in it to admit the acid freely both to the internal and external sides.

In the figure is represented a series of a dozen pairs of Grove's battery, in the order in which they are commonly arranged.

1179



Bunsen's battery is very generally used on the continent of Europe. Cylinders of carbon, in contact with the nitric acid, are substituted for platinum, the carbon being moulded to an iron tube, by coking pounded bituminous coal therein. By soaking the coke in sugar, and calcining it a second time, great compactness is given to the cylinder.

The Dry Galvanic Pile of De Luc is constructed of sheets of paper, coated on one side with gold or silver leaf, and alternated with thin leaves of zinc. By means of a circular steel punch, about an inch in diameter, discs may be cut out of sheets of this paper foil, all of one exact size, adapted to be packed neatly together in a long glass tube. The atoms of the leaves of zinc very slowly become united with the atoms of oxygen of the air recoiling to their natural polarized conditions of groupings of an oxide, whereby a feeble propagation of electro-dynamic action is sustained during surprisingly long periods of time. Mr. Singer constructed a dry pile of 20,000 series of discs of silver, zinc, and writing paper, which propagated an intense electro-dynamic action, like that produced by frictional electrical machines, causing a pair of pith balls of an electroscope to become divergent. A pith ball suspended by a silk thread between two metallic knobs, one connected by a wire with the top cap of the pile, and the other with the lower cap of the pile, continued to vibrate unceasingly between the two knobs during several years. A thin glass jar containing fifty square inches of coated surface, charged by ten minutes contact with the column, was found by Mr. Singer to propagate sufficient electro-dynamic action to fuse one inch in length of platinum wire of the diameter of $\frac{1}{5000}$th part of an inch. He states that an efficient Pile may be made of one kind of metal only, as of zinc foil, if one side be made bright, and thus rendered more readily oxidizable than the opposite surface.

The black oxide of manganese contains an extraordinary excess of oxygen, capable of freely uniting with zinc and other metals. Zamboni improved De Luc's Pile by coating one side of the paper discs with this substance, mixed with sulphate of zinc, and the other side with tin foil. These piles are capable of developing sparks across a space of air of $\frac{1}{16}$th of an inch, and also of producing chemical decompositions.

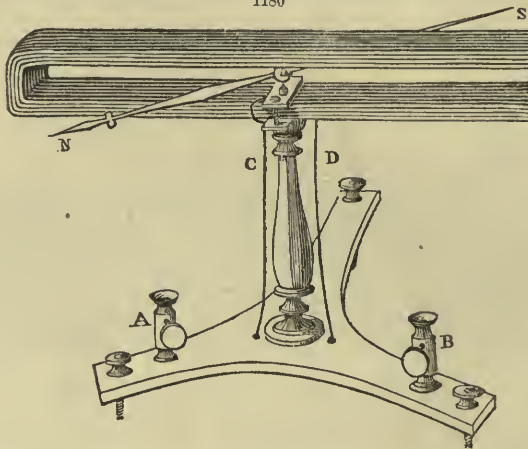
Taking advantage of the long sustained electro-motive power of the pile, an ingenious experimenter, Buzengeiger, attempted to render it available for operating the pendulum of a clock. By means of this arrangement of a Dry Pile, the pendulum was alternately attracted and repelled. It was thus made to move the clock-work, instead of receiving its motion therefrom, as in ordinary clocks. In the year 1815, he thus succeeded in constructing the first *Electrical Clock* ever propelled by electro motive power.

A great variety of other arrangements of galvanic batteries have been constructed with different kinds of metals, some of them with iron plates instead of zinc, and others to be operated upon by alkaline solutions, instead of acids. To describe them all would far transcend our limits.

Tests of Galvanic Action. The fact of the propagation of electro-dynamic action in the modified form denoted by the term "electric currents," is judged of by the test of the simple movement of the magnetic needle in swinging around on its pivot. The *degree of intensity* of the electro-dynamic action propagated, is judged of by the test of the extreme extent of the angle of its divergency from its natural north and south position; whilst the *direction* of the propagation of the electro-dynamic impulses near the needle is judged of by the particular crosswise direction in which a particular pole of the needle is urned or deflected to one side or the other.

Schweiger, in Germany, reasoning that if a single current passing directly along on one side of a magnetic needle exerted sufficient force to turn it on its pivot, it might be expected that by multiplying the circuits of the same current about the needle, the intensity of the electric forces would become multiplied to the same extent as the number of circuits, he accordingly wound numerous turns of copper wire (coated with silk to insulate from each other the overlapping coils) about a small piece of board. On withdrawing this piece of board, and inserting a magnetic needle within the cavity of the flattened coils of wire adapted to admit the needle to work freely therein, he constructed the *Galvanometer*—one of the most useful and important instruments now employed for testing the presence of the slightest propagations as well as intensity of electricity in motion; for in passing several hundred times about the needle, both above it and beneath it in the returning convolutions of the wire, its influence becomes correspondingly multiplied. Hence this instrument was originally called a "*Galvanic Multiplier*," as exhibited in the figure. N S, represents the needle inserted between the multiplied coils of wire, the ends

1180



of which, C and D, are extended downwards to the binding screws, A B, which are used for receiving and confining the ends of the conducting wires connected with the galvanic battery, or other bodies subjected to electrical excitation.

In using the galvanometer to measure the intensity of the electric force by the divergency of the magnetic needle, it is also to be noticed, that the scale of degrees marked on the circle does not denote the absolute force excited. A feeble electric current may cause the end of the needle to swing around over 10°; but by doubling the power of the current, it does not become urged to swing around 20°. The reason for this is obvious, the action of the deflecting force being reduced nearly in the ratio of the square of the distances of the separated conducting bodies and poles of the magnetic needles, and the action of the magnetism of the earth to bring back the needle to its north and south position being increased in proportion as the needle becomes turned more nearly at right angles to the north and south meridional lines.

For very delicately testing slight electric disturbances in experiments with the galvanometer, it is usual to employ an Astatic Needle, composed of two needles with their north and south poles reversed and confined together, to neutralize each other's terrestrial magnetism. This needle will remain stationary in whatever position it may be turned. The action to be tested is applied to the upper or lower needle, both being environed by spiral coils of the conducting wire.

In using a magnetic needle as a *galvanometer* to measure the intensity of electro-mechanical impulses, it is preferable to suspend it by silk cord or fine wire, requiring some exertion of motive power to produce a twisting, caused by the movement of the needle. The *torsional* resistance in this case becomes a test of the extent of the electro-dynamic action; whilst the deflections of the needle may be limited to a range of only about 20°.

Thermo-Electricity. Dr. Turner reduces the sources of heat to six in number;—1, The Sun; 2, Combustion; 3, Electricity; 4, The bodies of animals during life; 5, Chemical Action; 6, Mechanical Action. All these sources of heat are also sources of electrical excitation.

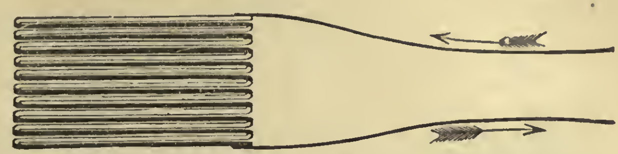
Thermo-Electric Batteries. The metals selected experimentally for producing the most intense excitation of electricity by means of heat, are German silver and silver, bismuth and antimony.

In experimenting with thermo-electric batteries formed of plates of bismuth and antimony, the bismuth being fusible at a low temperature, a very moderate heat must be applied. For this reason German silver and brass are preferred, as they admit of being safely excited by the contact of the red-hot iron, which will melt the bismuth.

To render the arrangement of the series of plates or wires of a thermo-electric battery more compact, they are laid side by side, as shown in the figure. They are insulated from each other by pasteboard, except at the ends, where the respective plates of bismuth and antimony, or of German silver and brass, are alternately soldered together, as in the arrangement of the series of plates of a voltaic pile.

The figure represents a series of ten pairs. The heat of the palm of the hand held in contact with the soldered ends of this battery induces sufficient excitation to affect a galvanometer needle.

1181



A more perfect thermo-electric battery is commonly constructed as exhibited in fig. 1182, consisting of 60 pairs of plates of bismuth and antimony, each ¾ of an inch broad, and ¼ of an inch thick. They are packed together in a case, B; but are insulated from one another, except at the soldered junctions of their ends, as above stated. The soldered ends of one series are arranged together on the under side of the case, where they may be heated by the radiation of the hot iron plate E, the edge of which only is

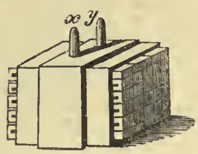
1182

exhibited in the cut. The opposite series of the soldered ends are arranged together on the upper side of the case, as seen at A, which forms a reservoir for receiving a refrigerating mixture of snow or ice and table salt. The plates are insulated from each other, and from the case, by pouring fluid plaster therein; which also serves to render the consolidated mass impervious to the water resulting from the melting ice.

By thus combining two extremes of temperature at the opposite ends of the plates, there is produced a correspondingly extreme disturbance of the temperature of the plates, and development of electric forces, as tested by the two conjoined iron semi-circles D, environed by a coil of the conducting wire C; whereby "a weight of forty or fifty pounds is required to separate them." Indeed, this thermo-electric battery is adequate to exhibiting various electro-magnetic phenomena which a galvanic battery is commonly used to exhibit; and also to give shocks and sparks.

The mechanical forces brought into action upon the needle of a galvanometer by slight disturbances of temperature, have been recently illustrated in an interesting manner by the experiments of Nobili and Melloni in France. The thermo-electric battery employed by them consisted of fifty small bars of bismuth and antimony, forming a bundle about one and a half inches long, and about one inch in diameter, inclosed in a band, as shown in the annexed figure. To facilitate the radiating and imbibing properties of the two extremities of the bundle of bars, the conjoined ends are all blackened. The extremities of the circuit are terminated at the two poles x, y.

1183



The bars of antimony and bismuth are insulated from each other by coatings of dry paper or silk throughout their lengths, and are soldered together alternately at their ends. The terminating bar of each series is separately connected with the ends of a wire forming the coil beneath the galvanometer n, m, fig. 1184, in the same manner as the copper and zinc plates of a galvanic battery are connected by the wires g and h, with the battery poles x, y of the preceding figure.

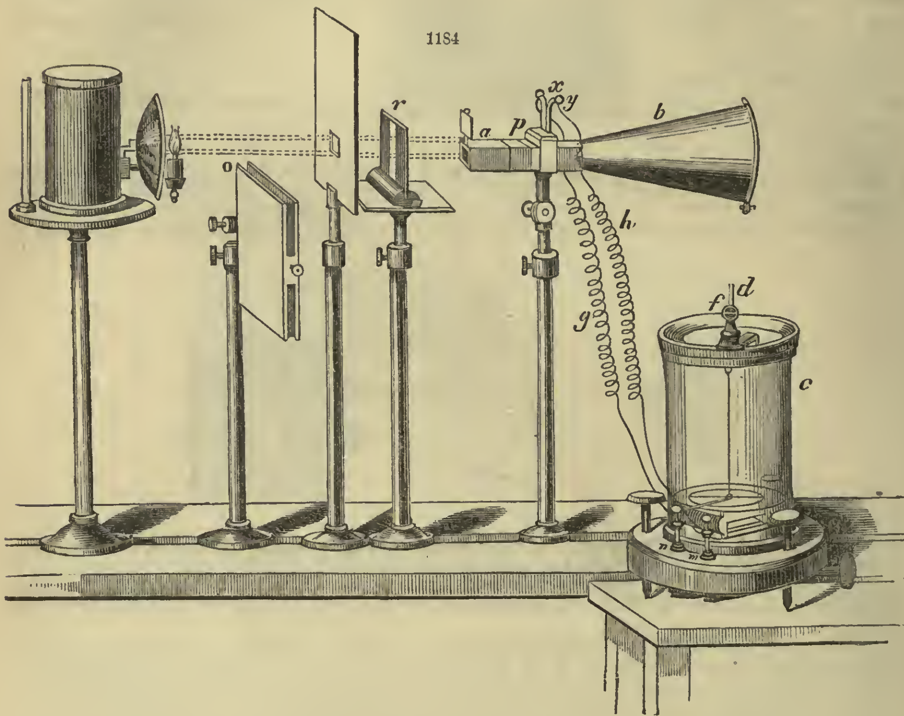
In the position of the instrument indicated in the figure, it is intended to denote at p, the blackened ends of the bars of the thermo-electric series, heated by a lamp, with a reflector. The dotted lines, representing the radiation of the heat through the aperture of the screen r; whilst the temperature of the other ends of the bars P, remains the same as that of the surrounding air.

The heat of the lamp induces a disturbance in the electrical equilibrium of the bars of antimony and bismuth. The electricity is determined to move in one uniform direction in a closed circuit through the conducting wires soldered thereto, and through the coil in proximity to the galvanometer needle; which is thereby swung around on its pivot. To prevent local disturbances of the needle by currents of air, the galvanometer is inclosed under a bell-glass, and is suspended from d by a very flexible fibre of silk. At o is a movable screen, designed to intercept the propagation of heat from the lamp, when an experiment is suspended.

The least radiation of heat from a lamp, or from the bodies of living animals, presented before the aperture of this instrument, causes the needle of the galvanometer to move around on its pivot. This thermo-electric battery, taken in connection with the appended galvanometer, constitutes a far more sensitive test of the approach of a warm body than the most delicate thermometer. The approach of a person within thirty feet of it, caused the needle to move, as stated by Nobili and Melloni. The slight heat of the bodies of insects, of phosphorescent wood, putrefying fish, &c., was thus detected. The ap-

paratus, therefore, constitutes a most sensitive THERMOSCOPE, far transcending the powers of any thermometer. A change of temperature of only $\frac{1}{1500}$th part of one degree of Fahrenheit's scale produces a perceptible movement of the needle!

1184



In the excitation of electricity by electrical machines, the movement of one portion of matter near another at sensible distances, each carrying with it its respective electrical atmosphere, reciprocally disturbs the state of rest of these atmospheres, and produces the phenomena of electrical excitation. This mode of exciting electricity by means of electricity, has received the name of *Inductive Excitation*, and constitutes a general law of the propagation of impulses through the medium of electric matter.

The propagation of action of electric currents across a space intervening between two conducting bodies, through the medium of the electric matter diffused throughout the atmosphere, appears to have been first noticed by Professor Faraday in the year 1832, and described in the "Annals of Philosophy," among the "proceedings of the Royal Institution."

"If two wires, A and B, be placed side by side, but not in contact, and a voltaic current be passed through A, there is instantly a current produced by induction in B, in the opposite direction. Although the principal current in it be continued, still the secondary current in B is not found to accompany it, for it ceases after the first moment; but when the principal current is stopped, then there is a secondary current produced in B, in the opposite direction to that first produced by the inductive action, or in the same direction as that of the principal current."

The nearer the circuits are approximated, the more intense is the resultant disturbance of the state of rest of the electric matter in the form of powerful sparks and shocks. For this reason thin plates of metal are wound into coils like ribbons, and substituted in place of wires, approximated only at arcs of their circumferences. The sides of the ribbons of metal are of course to be insulated from actual contact with each other by an intervening coating of silk or varnish.

1185

By using a coil of this copper fillet of the width of an inch, and of the length of two hundred and thirty-four feet, Mr. Noad states that a pair of zinc and copper battery plates of only $\frac{1}{8}$th of an inch in length and $\frac{1}{20}$th of an inch in width, were adequate to propagating sufficient electro-dynamic action to become manifest in sparks, on rapidly breaking and renewing the contact with the battery circuit; and with a large battery very brilliant sparks were visible.

The phenomena of the mechanical action of these *initial* and *terminal secondary currents* have been elaborately developed by the experiments of Professor Henry. He states that when the length of the wire in the coil of a helix is increased, the power of the battery continuing uniformly the same, the intensity of the shock is correspondingly increased, until finally, the greater resistance opposed by very long wires, to the passage of the primary exciting current, serves to counteract,

and even to reduce the intensity of the shocks. Whilst the shock from a small battery is increased by the intervention even of a short ribbon coil, that from a large one did not appear to be much increased thereby. But when the length of the coiled wire is increased in proportion to the increase of the size of the battery, then the intensity of the shocks becomes surprisingly increased.

He found that the current from a battery of 16 pairs of Cruikshank's arrangement, which produced only very feeble effects when transmitted through a short ribbon coil, gave shocks *too strong to be taken through the body*, when transmitted through a spiral coil of copper wire $\frac{1}{16}$th of an inch in diameter, and five miles long.

Whilst the intensity of the shocks of the secondary currents is thus increased by the extension of the length of the wire, the power of the primary current becomes correspondingly decreased as tested by its power of heating fine wires red-hot, and of deflagrating thin sheets of gold leaf, and of other metals. It was found also by Professor Henry, that these *secondary* currents produce the effect of inducing *tertiary* currents, and in like manner, subordinate currents of *fourth and fifth orders*, even up to the seventh, have been discovered to be induced in a series of coils!

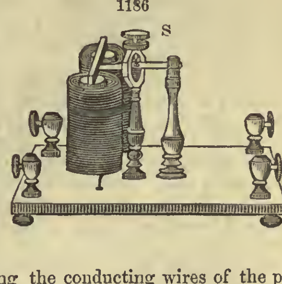
The remarkable facility of propagation of mechanical action through the medium of electric matter, by inducing the electro-polarization of series of atoms constituting conducting bodies, has been illustrated by many interesting experiments. The following demonstrate that the electro-polarization of a conducting wire is propagated not only through floors of rooms and other intervening bodies, to induce their electro-polarization, but even through great distances of intervening atmosphere. "A copper wire was suspended by silk strings around the ceiling of an upper room, so as to form a parallelogram of about sixty feet by thirty on the sides; and in the cellar of the same building, immediately below, another parallelogram of the same dimensions was placed. When a spark from an electrical machine was transmitted through the upper parallelogram, an induced current was developed in the lower one, sufficiently powerful to magnetize needles, although two floors intervened, and the conductors were separated to the distance of thirty feet. Two wires, about four hundred feet long, were stretched parallel to each other between two buildings; a spark of electricity sent through one produced a current in the other, though the two were separated to the distance of three hundred feet; and from all the experiments it was concluded that the distance might be indefinitely increased, provided the wires were lengthened in a corresponding ratio."

To prove that the same effect is produced by the action of the electrical discharges in the form of lightning in the heavens, Professor Henry made the following modification of the foregoing arrangement: "One of the wires was removed, and the other so lengthened at one end, as to pass into my study, and thence through a cellar window into an adjoining well. With every flash of lightning which took place in the heavens, *within at least a circle of twenty miles* around Princeton, sewing needles were magnetized in the study by the induced current developed by the wire. Being led from these results to infer, that induced currents must traverse the line of a railroad, I found that sparks were seen at the breaks in the continuity of the rails, at every flash of a distant thunder-cloud."

Professor Page gives the result of one of his experiments, made with a galvanoscope, connected with the metallic roofing of the Patent Office building, containing an area of twenty-two thousand feet of surface exposed to the atmosphere, and a plate of copper buried in the earth adjacent thereto. "I may safely say that the needle is affected by a flash of lightning one hundred miles distant."

In order to exhibit the experiments of secondary currents, and the consequent shocks and sparks, various kinds of machines or electrotomes have been invented for the express purpose of breaking and renewing the contact of the ends of the conducting wires with extreme rapidity. A self-acting electrotome, contrived with movable parts, to be operated by the motive power of the battery current itself, is now manufactured, for applying very conveniently a series of intense shocks for medical purposes.

1186



The primary current from a galvanic battery or magneto-electrical machine, is propagated through coils of insulated or coated wire wound about the two vertical ends of a bar of iron, bended to the form of the letter U, as shown in the figure; whereby this piece of iron is converted into a temporary electro-magnet, whilst the current circulates about it. Directly above the tops of the prongs of this temporary magnet is a piece of iron, serving as a *keeper* or *armature*, sustained by a spring, which allows freedom of motion to the cross-bar to descend in obedience to the attractive impulses, and causes it to rise from the ends or poles of the U shaped bar, at the moment the current ceases to circulate about the coils. The distance to which the cross-bar is lifted by the spring above the tops of the ends or poles of the electro-magnet, is adjusted by the screw S, which depresses the spring by the contact of its lower end therewith. The screw cups at one end of the machine are designed for receiving the conducting wires of the primary current from the battery, and are connected by wires beneath the base-board with the ends of the spiral coils wound about the bended iron bar. Leaving the extremity of the wire of the coils, the current flows beneath the base-board into the brass pillar, and through the screw S and flexible spring to the adjacent brass pillar, to which one end of this spring is attached. Descending this pillar the current is transmitted by wires beneath the base-board to one of the screw-cups at the end farthest from the electro-magnet, and thence through the circuit of the arms of the experimenter or through a connecting wire uniting the two screw-cups to the fourth cup adjacent to the electro-magnet, from whence it completes its circuit to the exciting battery. By this arrangement the electric shocks are propagated from the same wire which transmits the primary current.

When the connection with an excited battery is formed, the current transmitted about the coils environing the U shaped bar of iron converts this bar into an electro-magnet. The armature is instantane-

ously drawn down in contact with the poles adjacent thereto, depressing the flexible steel spring from its pressure and contact with the point of the screw S. Its contact therewith is thus broken; and consequently, the further circulation of the electric current about the wire coils wound around the poles of the U magnet is cut off. The immediate effect of thus cutting off the current is the cessation of further electro-magnetic action on the armature; which, on being released from its constrained position is urged upwards by the action of the flexible spring, until it comes in contact with the end of the screw S. This contact restores again the circulation of the current, which, in turn, again restores the electro-magnetic action, and brings down the armature. The separation of the spring from contact with the end of the screw is again produced, and this operation is repeated with such rapidity as to produce a humming sound, like that made by the rapidly-vibrating wings of a bee.

In his "Experimental Researches," Professor Faraday has classified the propagation of electro-dynamic action under three heads viz: by *Disruption*, *Conduction* and *Convection*.

Considering that all bodies which serve to propagate impulses of mechanical force through the medium of electric matter, represent simply pathways of electric currents, he has applied the term ELECTRODE to denote conducting bodies. To that particular end of the electrode at which the current is supposed to enter, he has given the name of ANODE, and the term CATHODE has been similarly adopted by him as a suitable term to denote the point of departure of the current from a conducting body. But instead of the idea of regularly flowing currents from atom to atom, and mass to mass, throughout the whole length of conducting wires and other bodies, it would be preferable to adopt the idea of the simple propagation and reception of mechanical impulses constituting the phenomenon of polarization, through the medium of the electric matter existing in connection with groupings of atoms, corresponding with the propagation of mechanical action by the undulatory waves of fluid water and air. On the surface of quiet waters the waves may be seen propagating the impulses simultaneously imparted to them from numerous disturbing causes, in equally numerous relative directions, the undulations crossing and recrossing each other, and even running in opposite directions, without interference. A similar result occurs in the propagation of impulses through the air in the modified form of sounds. The electric waves of polarization appear to be similarly propagated through the medium of the perfectly mobile electric matter by the waves of polarization of the atoms of the telegraphic wires.

Table of several substances arranged in the order of their Conducting Powers.

Silver,	Steam,	Cotton,
Copper,	Rarefied air,	Feathers,
Brass,	Oils,	Hair,
Iron,	Lime,	Wool,
Platinum,	India-rubber,	Silk,
Charcoal,	Siliceous stones, } in proportion	Diamond,
Dilute acids,	Argillaceous, } to hardness.	Glass,
Solutions of salts,	Porcelain,	Wax,
Metallic ores,	Baked wood,	Sulphur,
Animal fluids,	Dry air and gases,	Resin,
Pure water,	Leather,	Amber,
Snow,	Dry paper,	Gum lac.
Living vegetables and animals,		

CONVECTION. It has been noticed that the molecules of air, turpentine, &c., on becoming polarized are urged from the battery pole, thus propagating the electro-dynamic action in the modified form of mechanical movements of the atoms. These movements are considered as wafting the electric matter across a space occupied by air; and hence the term "Convective," has been applied to designate this mode of ferriage of electric matter, instead of its propagation by mechanical action through the medium of electric matter.

The term "disruptive" implies a breaking through, and is figuratively employed to denote the noisy discharges of lightning or electric sparks through the air. This mode of propagation is manifestly effected by *breaking through* the fluid atmospheres of all gaseous or aeriform particles, as the term *disruptive* implies. The propagation of mechanical action through the atmosphere appears therefore to be effected directly by displacing the particles in its progress, and by opening a void space therein. That this result is really produced by disruptive discharges of electricity is proved by the fact that sounds are caused by the collapsing of the displaced air into the void space left as an open pathway through a portion of transferred fluid. Sounds are similarly produced by the collapsing of the air into the void space produced by the action of a whip-lash in *snapping* it. The prolongation of the continuous sound of thunder-peals, or of "rolling thunder," is ascribable to a difference in the velocity of the propagation of sound and of electro-dynamic action. The undulations of the air advance with the velocity of only 1130 feet per second, or a little more than a mile in five seconds; whilst the undulations of the electric medium are propagated about a million of miles in the same period.

The various expedients devised for the protection of buildings, and of the occupants of them, from injury by disruptive discharges of lightning, are all founded on the principle of providing some more readily polarizable body than the materials employed by masons and carpenters in the construction of edifices.

* *Lightning Conductors.*—The first lightning conductors consisted merely of metallic rods or chains proceeding from the highest point of the building or the ship, in a direct line to the earth or sea; but this was not found in all cases sufficient. Instances have occurred in which the conductors have been fused or

* Aide Memoire to the Military Sciences.

shattered, and hence arose a prejudice against their use, under the idea that they did more harm than good, by inviting the destruction they were intended to prevent. An attentive examination, however, of numerous cases of damage from lightning has shown that the path of discharge from the cloud to the earth is always in the line of least resistance. This line may not be the shortest lineal distance, but it is in all cases the shortest electrical distance; that is, the lightning picks out the best conductors in its transit to the earth, selecting with the nicest discrimination metal cramps and fastenings, and by its expansive power shattering and destroying inferior conducting substances, such as wood, brick-work, and stone.

The following diagrams from experiment, illustrate this principle fully:

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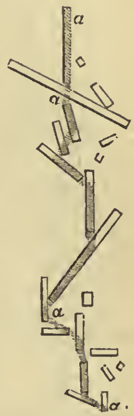
1182.



Figs. 1182 and 1183. The shaded part shows the direct track *a a* taken by the electric fluid along a line of metallic conduction, disregarding every thing but its own course. Fig. 1182 may represent the conducting masses in a building. Fig. 1183, the passage of the fluid across the bight of a wire-rope, or of a chain.

Hence the principal danger in using chain or wire conductors in the upper masts of shipping, as when these last are lowered they are apt to leave the chain or wire-rope hanging loosely; and when handling this as a bight, the seaman's body becomes the shortest course (*a' a'*, Fig. 1183) for the electric action, on the very same principle that a metallic rod-conductor of proper dimensions may be passed through a barrel of gunpowder with perfect safety, though a chain would ignite it at once.

To guard effectually a structure from the stroke of lightning.—First: The conductor should be of metal, and one of the best conducting metals should be selected. Second: The conductor should be capacious. Third: The conductor should consist of several branches with pointed rods projecting freely into the air from distant summits of the building, and connected by horizontal branches passing along the ridges, and from these sending off other branches to the ground.

Copper is the best conductor: the rods should not be less than half an inch diameter, if solid; three-fourths of an inch is preferable, and generally ample. If hollow, they may be from 1 to 2 inches in diameter, and about one-fifth of an inch thick.

If iron rods be used, they should not be less than three-fourths of an inch diameter when solid: if hollow, not less than 2 inches diameter and three-tenths of an inch thick, and jointed.

The hollow conductor (if sufficiently thick for stability) is better than the solid rod of equal length and weight, because the metal should display as much surface (in lateral dimensions) as possible consistently with strength, to reduce the intensity of action on surface, and heating effect in transverse sectional area; but unnecessary length should be avoided.

The conductor should involve in its course the principal detached masses of metal in or on the actual walls and framing of the building or ship: if not allowed this course freely, it will be apt to take it in a summary and violent manner. Figs. 1188 to 1192.

It should be placed as close as possible to the walls, &c., which are to be defended,—not at a distance from them; and should be carried down at once directly into the ground; and when below the surface, it should then divide into two or more pointed branches *a a a*, Fig. 1187, slanting away from the building. If circumstances permit, the lower end should pass into a well, or a stream, or a drain, or at all events into earth that can generally be kept moist from any neighboring gutter. It is a useless precaution to pass condctors through glass linings and holdfasts, as has been recommended, since the lightning will always take the direct course down the rod until interrupted; on which last account chain conductors are very inferior to those of rod, being a series of interrupted conductions from which the lightning is ready to turn aside at any point of contact of the links,—provided that at such point a freer and easier line of conduction be offered by some neighboring body than what the chain itself affords.

The conductor should be attached to the most prominent points of the building, Fig. 1190: if its length be very considerable, its transverse dimensions must be increased; and in doing this, the provision for a sufficient conducting surface insures that for the heating effect.

In ornamental buildings, such as honorary columns, &c., for the sake of appearance, the conductor may pass down withinside; it must, however, be firmly fixed, and the line of conduction made and kept complete and undisturbed.

In extensive ranges of buildings, all the most prominent points should have long pointed rods projecting freely into the air, at least 4 or 5 feet above the building; and the larger the range the higher they should be. Fig. 1190.

It does not appear that any single conductor hitherto made can insure beyond a horizontal radius of 40 feet; hence, in practice, less should be taken; though a wider range may be allowed if the roofs be of zinc, lead, copper, or any other metal in *well-connected* sheets; or if the ridges and hips only be thus guarded, and the whole well joined to the conductor, and to iron gutters and pipes, now commonly used, and a free passage be provided to the ground at different places. The points of contact must be numerous, to reduce the heating effect (or chance of fire) at such points, as the whole electric action will condense there, having still to pass through them on its way down. There is no reason why lightning conductors should not be painted or lacquered.

In addition to the diagrams given in Figs. 1184, 1185, and 1186, showing the construction of hollow conductors for buildings,—those for the protection of shipping, Figs. 1189 to 1192, are likewise noticed, as probably providing for the most complicated cases that are likely to occur in the most extreme cases on land.

Fig. 1184, the mode of joining two lengths of copper tube *a b* by means of a double screw *c* with a shouldered collar *d*.

Fig. 1185, the staple *a*, by which the conductor is supported at the joints and fixed to the wall.

Fig. 1186, the head of the conductor.

Fig. 1187, conductor complete, showing the lower termination *a a a* as buried in the ground, or received in water.

Fig. 1188, application of conductors; the points *a b c d e*, &c., connected by bands of metal *c n d t e h*, &c., into one general whole.

Fig. 1189, ships' conductors, consisting of two strips of sheet-copper, from 1·5 to 5 inches wide, and from 1-8th to 1-16th inch thick, in lengths of 4 feet. They are let double into a groove in the mast, so as to insure continuity of conduction by breaking joint, as shown in the figure: these strips are kept in thorough contact, and are secured to the mast by copper nails, 6 inches apart, in the drilled and countersunk holes *d a*. The upper surface of the upper piece A A is slightly rounded, so as to conform to the surface of the mast in transverse section.

Fig. 1190, the cap *a b* and the hole *b* through which the moveable mast *e x* slides, are furnished with similar plates; these are led from the square hole at *a*, by which the cap *a b* is fixed to the head of the mast D, into the round hole at *b;* and there is a lining of copper in this part of the hole next to the conductor at *b*, by which the metallic line is continued to the next mast D.

Figs. 1191, 1192, the bolts *a b c d e f*, passing through the ship, and in which the general line of conduction terminates, are clenched upon metallic rings and plates, in connection with the copper sheathing; and there are additional bands *m n*, Fig. 1191, leading from the fore-mast and mizen-mast directly to the stem or stern under the decks; other bands *g h*, Fig. 1192, traverse the beams, and they all terminate in the sea by bolts clenched on the copper sheathing. Fig. 1192 is a section suited to the beams abaft each mast.

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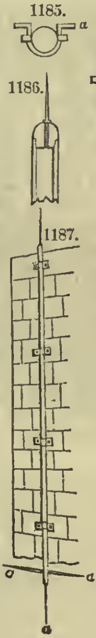

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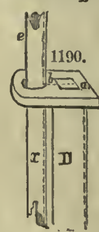
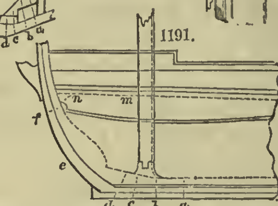


1191.



Electricity applied as a moving power.—The operation of voltaic electricity in magnetizing iron, and the disappearance of the excited magnetism directly its action is suspended, or nearly so, has furnished a means of obtaining to a certain extent a considerable moving force applicable to the purposes of machinery.

Mr. Cook, of Saratoga, made an interesting exhibition of an electro-magnetic machine, in the year 1838, in Barclay street, New York. The whole apparatus was of the most simple construction, consisting of two sets of magnets, one revolving within the other. The external magnets being excited by the fluid generated by the action of an ordinary galvanic battery, while the polarity of each magnet was constantly and regularly changing, a perfectly uniform motion was communicated to the cylinder, which might be increased indefinitely as additional force is applied. The machine was thirty inches in diameter, and contained seventy-eight magnets, each weighing four pounds. The machine, in full operation, made eighty revolutions per minute—considerably more than can be obtained by the force of one man.

Professor Jacobi, of St. Petersburg, by means of an engine on this principle, succeeded, in the years 1838 and 1839, in propelling a boat upon the Neva at the rate of 4 miles an hour. This boat was 28 feet in length, about 7 feet wide, and drew nearly 3 feet water. It contained 10 persons; the engine was worked by a voltaic battery of 64 pairs of platinum plates, excited with nitric and sulphuric acid, and propelled the vessel through the medium of paddle-wheels.

A large *Electro-magnetic Locomotive Engine* was constructed by Mr. Davidson, and tried on the Edinburgh and Glasgow railway, the account of which, with drawings, was published in the Practical Mechanics' and Engineers' Magazine, for November, 1842. The carriage was 16 feet long and 6 feet broad, and weighed above 5 tons, including the apparatus of batteries, magnets, &c. This Electro-magnetic Locomotive was propelled by means of electricity with a velocity of only about 4 miles per hour.

Professor Page, in his lectures before the Smithsonian Institution, exhibited a bar of iron weighing one hundred and sixty pounds, which was made to spring up by magnetic action, and to move rapidly up and down. The force operating on this bar, he stated, averaged *three hundred pounds*, through ten inches of its motion. He then exhibited his engine of between four and five horse-power, (operated by a battery contained within a space of three cubic feet,) with two feet stroke, the whole weighing about one ton. It made 80 strokes per minute, whilst driving a circular saw ten inches in diameter, sawing up boards into laths. He has since experimented with a locomotive engine on the Washington railroad. The engine was propelled at the average rate of ten or twelve miles in an hour. Many other experiments have been made, but as yet no machine has been produced practically useful.

Amongst other applications of electricity to useful purposes, the application of magneto-electrical action in arresting the oscillations of the compass-card on board ship is not the least important. Electrical currents are excited in non-magnetic metals, such as copper, zinc, &c., when placed near a magnet in motion, or when themselves set in motion near a magnet; and these currents so tend to arrest the motion, that if an ordinary magnetic needle be caused to oscillate within a ring of copper, the amplitude of the oscillations rapidly diminishes, and the needle is speedily reduced to rest. On this principle, the common compass-card employed at sea is placed within a dense ring of copper,—the poles or extremities of the magnet being near the interior of the ring; this, with some valuable and judicious improvements in the construction and mounting of the needle, so fetters the vibrations, that even although the instrument be extremely sensible of the least motion, and of the action of the magnetic force of the earth, yet the compass-card is found steady in the heaviest sea, and under the violent motion of steamboats when struggling with a gale.

For further and still more important applications of electricity to the improvement of the arts, and the conveniences of life, see the following articles: also, BLASTING and TELEGRAPH.

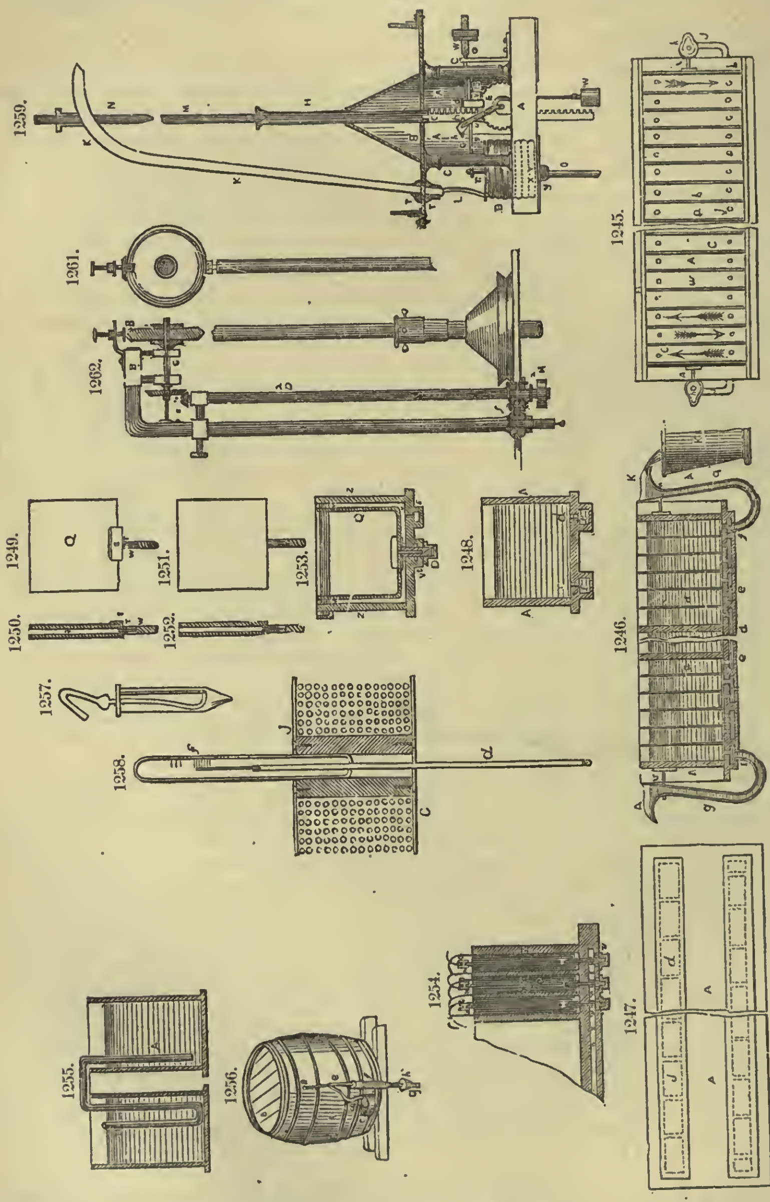
ELECTRIC LIGHT. The improvements in the construction of galvanic batteries consist in making them on what is termed the "perfluent" system of supply and discharge, to contradistinguish it from the "percolating" system, which has recently come into extensive use. According to the percolating system, the liquid employed (usually sulphuric acid) is supplied to and discharged from each of the cells of the battery, in separate and distinct streams or series of drops; the liquid, as it becomes exhausted, though not entirely so, dropping out through an orifice in the bottom of the cell, and being then allowed to run to waste, and the place of the discharged liquid being supplied by fresh drops descending from above into each cell. But, according to the new system, the liquid is supplied in one stream only, which passes continuously through the entire series of cells, entering by the first cell of the series, and passing off through the last. No diminution of electric intensity is observed to take place in the perfluent battery, from bringing the cells into communication with one another, owing to the circuitous course which the fluid is made to take between cell and cell. In proportion, of course, as the duration of the transit through each cell is shortened, the chance must be proportionally lessened of each portion of the liquid coming into contact with the acting metal or element in that cell; yet, as no drop of the fresh liquid supplied to the battery can make its way to the final discharge outlet without going through the whole of the cells, what it misses in the first cell, it is sure to encounter in one or other of the remaining cells. The cells last in order of a perfluent battery necessarily act less powerfully than the earlier cells of the series; as, for example, the last six cells of a series as compared with the first six. The diminution of power, that is to say, the quantity of electricity which the cells are capable of circulating, does not appear, however, to follow exactly in the ratio of the strength of the exciting liquids; for the difference in power between the middle and initial cells of a series is proportionally not so great as the difference between the middle and the terminal cells. When it is desirable to obtain intensity in the electric current rather than great quantity, the terminal cells should be made about equal to the quantitative power of the others, by uniting the similar conducting wires of several cells together, and using them as if proceeding from one cell. Thus, as it would be technically expressed, the last three cells in a fifteen-cell battery (say the 15th, 14th, and 13th) might be connected for quantity, and the two next preceding pairs (say the 12th and 11th, and 10th and 9th) be connected also for quantity, and the first eight cells might be worked singly, in the usual manner of a series. But, however great may be the differences in power between the initial, middle, and terminal cells of a series in each cell, regarded by itself apart from the others, the degree of exhaustion, and consequently of electric action, is always very nearly uniform throughout every part of the cell.

The details of a battery constructed on this perfluent principle are represented in Figs. 1245, 1246, 1247, and 1248 of the drawings annexed. Fig. 1245 is a view of the battery, as seen from above; Fig. 1246 is a vertical longitudinal section; Fig. 1247 is a view of the trough from beneath; and Fig. 1248 is a vertical cross-section. A is a wooden trough, the parts of which are firmly bolted together; *a a* are slate partitions, the edges of which fit closely into the sides and bottom of the trough, and are about two and a half inches apart; *b b* are thicker partitions of wood, which are inserted at short intervals, say every six cells, and made fast to the sides by screws and nuts; $c\,c^1$ are two parallel rows of holes made in the bottoms of the cells, two in each; $d\,d^1$ are two corresponding rows of wooden covers, which are made fast to the bottom of the trough, Fig. 1247, one underneath each adjoining pair of holes, as $c\,c$ or $c^1\,c^1$, with the exception of the two end ones, which cover one cell only; *e* is a groove cut out in the upper surface of each cover, and made just of width enough to embrace two of the cell holes, as $c\,c$ or $c^1\,c^1$, and so establish a channel of communication between them; *f* is an aperture made in the bottom of the end cover of the series of holes; *d* and f^1, similar apertures in the bottom of the opposite end of the same series of holes, into each of which apertures there is inserted a piece of copper tubing, to which there is attached one end of a flexible hose, *g* or g^1, (made of vulcanized caoutchouc, gutta percha, or any other suitable substance or combination of substances,) which terminates at the other end in a funnel *h* or h^1; and $i\,i^1$ are eye-bolts affixed to the ends of the trough on the outside, which respectively sustain in an upright position the funnels *h* and h^1, there being a slit or opening in the eye of such bolt, to admit the neck of the funnel. The whole of the inside of the trough is well coated with marine glue.

The mode of operation with this apparatus is as follows: The liquid is poured in at the funnel *h*, and passes into the first cell through the hole *o* of that cell; from the first cell it goes out through the hole *e* into the first of the grooved covers of the series *d*, whence it flows into the second cell through the hole *c'* of that cell; from the second cell it next passes through the hole *c* of that cell into the second of the grooved covers of the series *d*; and so on to the end of the series, (as indicated by the arrows in Fig. 1245,) when it discharges itself through the flexible hose *g'* and *h'* into a receiving vessel K.

The arrangement just described is, however, chiefly suitable for those batteries which use but one sort of exciting liquid, but in batteries where two fluids are used it may be expedient to adopt the modifi-

cation of the perfluent system represented in Figs. 1249 to 1254. The internal cells in this case are supposed to be made of earthenware or some other porous material. Fig. 1249 is a side view of one of these cells, and Fig. 1250 a vertical section across the middle. A hole Q is made in the bottom of this cell, and into this hole a varnished copper tube *r*, with a collar and washer of vulcanized caoutchouc at top, is dropped. The tube is pulled tightly down upon the washer, in order to prevent any of the liquid escaping between the washer and the bottom of the cell. Or, instead of this arrangement, one of the escription represented in Figs. 1251 and 1252 may be substituted. S is a cradle which is cemented on



to the under end of the cell by marine glue, and encloses it completely. The tube *r* is screwed on to the bottom of this cradle, and through it up to the hole in the cell. In both cases the tube has an oval aperture *w* cut transversely through it, and terminates at its under end in a solid screw-point. The trough for the reception of porous cells of this description is made in the manner represented in Figs. 1253 and 1254; the former being a transverse vertical section of the trough through the centre of one of the cells, and the latter a longitudinal vertical section. Q is the internal porous cell and Y the zinc plate suspended therein. X X are the plates of negative surface, say copper, placed outside of the porous

cell. Z Z Z are the sides and bottom of the trough, the spaces *m m* between which and the porous cell form the external cell, which contains the second fluid, (say sulphate of copper.) A^a is an open channel for the discharge of the second fluid, which runs along the outside of one wall of the trough, near to the top, and communicates by lateral apertures *p p* in the wall, with the spaces inside *m m*, appropriated to that fluid. V is a grooved or channelled under-cover, which extends along the bottom of the trough from end to end, and comes immediately under the line of holes in the porous cells Q. The lower end of the tube *r*, which is attached as aforesaid to the bottom of each porous cell, and enclosed by the cradle, is passed downwards through an orifice in the bottom of the trough, and also through another orifice in the bottom of the under-cover V, till the oval aperture *w* in the tube coincides with the groove *t* in the bottom of V; so that when the whole of the cells are fixed in their places, the channel *t* forms through the medium of the apertures *w w* a common channel of communication between all the cells. U is a nut which takes on to the end of the solid screw-point of the tube *r*, and by turning which the parts S, *r*, V, and Z are all screwed tightly together. For the sake of greater security against leakage, and against the intermixture of one of the fluids with the other, washers of vulcanized caoutchouc are inserted between the crade S and the bottom of the trough, and between the bottom of the grooved channel V and the shoulder of the nut U. E is a second under-cover which runs parallel to V, (on one or either side of it;) the groove *e*, in which the second cover communicates by a series of holes *n n* with the external cells above, containing the second fluid, serves as a common channel through which these cells may be supplied from a flexible hose. The second fluid is, after passing through the external cells, discharged from the end of the channel A^a.

The perfluent system may be also carried into effect by employing siphons instead of the grooved under-covers *d d'*, V, and E, before described, to transmit the liquid from cell to cell successively, as shown in Fig. 1255, which represents two adjacent cells of a battery. The long end A of the siphon descends to near the bottom of one cell, in order that it may carry over the densest portion of the liquid therein, and deliver it through the short end B into the next cell. Or, if the liquid employed is of such a nature that it becomes lighter as it becomes exhausted, (sulphate of copper, for instance,) then the legs of the siphon are reversed, the liquid entering it by the short end, and being carried over by the long end.

Part of the invention consists in attaching to all galvanic batteries in which a gradual change of liquid is required, an equilibrated hydraulic cistern and graduated meter, such as represented in Figs. 1256 and 1257. A is a cask, closed at top, so as to prevent the action of the atmospheric pressure on the surface of the liquid contained in it; and *b* is an orifice near to the bottom, which opens into a small outer cistern *c*. This arrangement ensures that the liquid flowing through any channel from the little cistern *c* will always flow at the same rate, whether the cistern be full or nearly empty. From this little cistern a loose piece of vulcanized caoutchouc tubing *d* proceeds, and is connected with the glass tube *e*, from which is suspended the meter *f*, having a small hole at the bottom, so that the rate of flow out of this hole is indicated by the height at which the surface of the liquid stands. The meter is graduated to units, which shows the amount of flow requisite to supply the chemical action which is going on in the battery when the electric current is circulating at a rate indicated by corresponding units on the galvanometer described in Fig. 1258, which is included in the circuit. The meter, with its tube *d*, is suspended so as to enable the rate of flow to be adjusted by hanging it at an altered level in relation to the cistern, according as the galvanometer may indicate to be necessary. The parts *d e* form in fact a siphon, which only requires to be filled with liquid when the apparatus is first set in action, after the cistern is charged. The liquid issuing from the meter is received by a funnel *h*, or otherwise led to the battery.

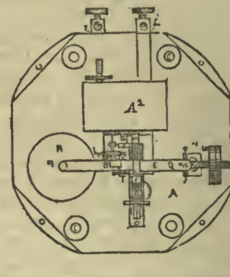
Also the employment in galvanic batteries, having copper or mercury for the negative element, of a liquid amalgam of zinc and mercury, enclosed in a bag or case of lawn or horse-hair cloth, or any other finely reticulated fabric, but not made of metal, which allows of the acid passing freely through its meshes to act on the bottom and sides of the zinc amalgam, while the bag or case retains the amalgam itself.

Again, the employment of lead as the positive element in galvanic batteries, (instead of the zinc which is now commonly used,) combined with a solution of nitric acid or of acetic acid, in some one or other of the forms best calculated to act on the lead.

The new galvanometer is such that it can be made a permanent adjunct to, or part of the battery, so as to be always indicating what amount of electricity is circulating when any sort of duty is being performed by it, and the weights of materials combining or used per minute at any particular time. This improved galvanometer consists of a thick piece of insulated copper wire A wound round a wooden or brass cylindrical centre, fitted with ends C C. One end of this coil is in metallic connection with the positive or negative pole of the battery, and the other extremity is placed in connection with the part of the lamp, (or other piece of mechanism for actuating which the battery is used,) which would receive the conductor from the said pole of the battery. In the hollow cylindrical centre of the coil there is placed a rod of soft iron *d*, as shown in the figure, which moves loosely up and down in it, and is prolonged by a short brass stem or index *e*. A graduated scale *f* is fixed to, and rises from, the upper end of the coil, so as to show the height at which the electric influence causes the index to stand. The graduations are represented in the figure as marked on a glass tube, within which the index and rod *d* slide. These graduations are so made as to indicate the number of grains of pure zinc consumed per minute in each cell of the galvanic series, the current produced by which causes the index to stand at each such division of the scale. Any galvanometer of this kind can be graduated from a standard one. The standard can be graduated by ascertaining experimentally the weight of zinc consumed per minute, but a less tedious process is to graduate it from a Petrie's Galvanometer, which indicates all the required units of electricity and their fractions, by means of weights; the accuracy of that instrument being first tested by one such direct experiment on the zinc consumed. This improved galvanometer may be made of a shorter and thicker wire, making fewer coils, if the iron rod is partially counterpoised by a spring or weights, or hydrostatically with mercury.

Figs. 1259 and 1260 are representations of a lamp embodying this improvement. The skeleton of this lamp is composed of a foundation-plate of wood A, a sole-plate B of brass, firmly connected by pillars C and a three-legged stand K rising vertically from the sole-plate B, the feet of which are fastened to B by nuts beneath, but insulated by circular washers of dry hard wood (of the form shown in section *i j*.) A hole is bored vertically down through the centre of the top of the stand K, into which hole the upper electrode N is fixed by three metal wedges jambed into key-ways or channels, sloping upwards and outwards, so as to keep the inner faces of the wedges parallel to the central axis. A glass shade is fixed to the sole-plate B so as to cover K. H G is a shaft which slides vertically into the central axis of the lamp, through holes in A and B, and has a socket at top which carries the lower electrode M. The lower part G is cut with teeth which work into a pinion F, which turns on a spindle in fixed supports. A barrel F′ is attached to the pinion F, and a weight W is suspended by a string which passes round F′ and is fixed to it, so as to counterpoise the weight of H G. On the spindle of the pinion F is fixed a wheel E, having square teeth. A lever T turns loosely on the same spindle as a fulcrum, and carries a double pawl U V, which turns on a pin which projects from the side of T, so that this pawl U V can lock into the teeth of the wheel E in either direction. A long horizontal lever Q passes over this pawl from a joint or fulcrum *a*, and this lever carries a light spring or tongue *l* close beneath it, the end of which is kept from springing away from the lever by resting in a step in a little stirrup or fork *d*, which is attached to the lever Q, and embraces the wheel E and the end V of the pawl. The pawl and its lever T are kept in a state of slow vibration from side to side by means of a crank S, which works in a fork at the end of T, the crank S being made to revolve by an ordinary train of wheel-work, furnished with an escapement or fly-wheel A², and driven by spring power or weights. When the lever Q is turned a little downwards its tongue *l* presses V into the teeth of the wheel E, and the vibratory motion of T causes V to drive the wheel round, notch by notch. The wheel does not follow the pawl in its back motion at every stroke, for this is better ensured by having a spring *n* (Fig. 1260) fixed to A, and pressing against the side of G. This motion of the wheel causes the pinion to elevate the rack G slowly, so as to raise its electrode M towards N. But when the lever Q is raised or turned upwards, the notch in the stirrup lifts the tongue *l* off V, and allows U, the heaviest end of the pawl, to drop into the teeth of the wheel E. This drives it round in a contrary direction, so as to lower the rack G and draw its electrode M further from N. Whenever the lever Q is raised, the lower step in the stirrup *d* catches the sides of V and draws it (V) up out of the teeth of the wheel, in case V should have become jambed or hitched in the teeth, so that the counter-weight of U might be unable to release it. The means by which the end of the lever Q is raised or lowered are these: R is a regulator coil, one end of its wire is connected with the binding-screw *e*, and the other end, L, is brought up and fixed in contact with K. An iron rod O moves freely up and down in the central hole of the coil, and is prolonged upwards by a stem of wood *p*, by which it hangs to the end of the lever Q in the manner shown in Figs. 1259 and 1260. The rod O passes through a hole in the centre of a cup *y*, which screws into the bottom of the coil-case. Around O there is a circular weight X which rests on a small step in O when O is raised. When O sinks below its medium position it is left behind, resting on the edge or rim of *y*. The object of this arrangement is, that when O is actuated by a force equal to its own weight, added to half the weight of X, then it will have a tendency to return to its medium position, with a force of half the weight of X, whether it be raised higher or sunk lower than that position. The mode of action is as follows: The end of the negative wire from the battery is set in the binding-screw *f*, and is conducted thence by a metal connection to the supports of the spindle of the pinion, and to the spring *n*. The current passes through these into the rack; thence to the lower electrode M, from which it passes to the upper one, N, producing the light between them. From N it proceeds through the stand K to the wire L, of the regulator; thence to the clamp *e*, which is in connection with the other end of the regulator wire, and into which the positive wire from the battery is clamped to complete the electric circuit. The current, in passing through the regulator, tends to raise the iron centre O, which being connected to the lever Q, is counterpoised by the weight W¹, which screws along an extension of the lever beyond the fulcrum *a*. To put the lamp into adjustment, the driving geer being wound up, and the battery being in a state of activity fit for the permanent action intended to produce the light, and its wires connected with *e* and *f*, as described, the lever Q is raised by hand until the electrodes have separated to the greatest extent compatible with obtaining a permanent light from them. The screwed weight W¹ is turned backwards or forwards until it keeps O balanced, just so as not to sink below its medium position, when the electrodes are separated as aforesaid. When in this position, the shoulder of O touches the weight X, which is resting on the rim of *y*. The lever Q carries a little projecting piece or catch *g*, which meets the bent arms attached to the crank-spindle S, and thus arrests the motion of the crank, when the lever lies so that O is in its medium position; but whenever it rises above or sinks below that point, the catch *g* allows *h h* to pass beneath or over it accordingly, so that the crank can revolve freely and work the ratchet U V.

1260.



A front view of a lamp on this plan is given in Fig. 1261, and a side or edge view in Fig. 1262. A¹ is the disk, which, as shown in section, Fig. 1262, resembles in its form two cones, placed base to base, so that there is always one sharp or feather-edge in sight of the negative electrode, which is of the ordinary single-cone form. B¹ is the scraper; B² is a frame which carries the shaft C², to which the disk electrode A¹ is attached. D² and E² are a bevelled wheel and pinion, which geer into one another, the latter being fixed to the shaft G². At the bottom of this shaft there is another wheel H², to which the clock-work or other apparatus for giving motion is attached. The shaft G² may be insulated in various ways, either by the interposition of plates of ivory or wood, J K, screwed together, or by gutta-percha or india-rubber rings.

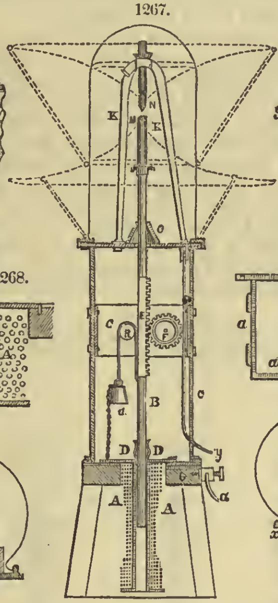
To increase the temperature of the metallic electrode A^1, the operator sometimes passes the metallic holders B B through a block of glass D D D, or some other similar bad conductor of heat, as represented in Fig. 1263, so that the heat and radiant light may be developed with as little loss of the former as possible by radiation.

An elevation of a small iridium bracket lamp is given in Figs. 1264 and 1265. A^1 is the electrode of iridium, which is fused on or otherwise fixed to two pieces of platinum B B, which are fixed into two copper or other metallic holders C C. These holders are insulated by means of ivory, wood, or vulcanized india-rubber washers D D, or some other suitable non-conducting substances, so as to prevent contact with the bottom metal plate of the lamp E. To one of the metallic holders a copper wire a^1, passing through the hollow tube B^1, is connected with one pole of the battery, and the electric circuit is completed, and the current made to pass through the brass-work of the lamp to the electrode, by turning the ivory knob X, which is attached to a screw-shank Z, making a metallic communication with the other holder. W Y is a ring of brass, which is screwed into the bottom of the lamp. A glass shade, of any shape or form, may be placed on the plate E.

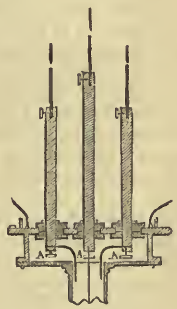
Fig. 1266 represents a triple electrode suspending-lamp. A A A are three ivory knobs, with metallic shanks, for making the necessary communication, as before described.

An apparatus embodying the chief of these arrangements is represented in Fig. 1267. The parts in this apparatus which are similar to those in the permanent light apparatus, Figs. 1259 and 1260, before described, are indicated by similar letters. A helix coil of insulated copper wire A, is employed for the purpose of producing the prime-moving force which actuates the sliding shaft which holds the electrode. This helix is fixed to the bottom of the framework C C′ C″. A cylinder of soft iron, B, moves freely up and down in it; to the top of B is fixed the rack E, which slides through the hole at c'', and carries the electrode M, fixed in a socket, so that this shaft can move the electrode M to or from the lower end of the electrode N, which is fixed in the top of the tripod K by wedges or screws. K is fixed and fur-

1267.

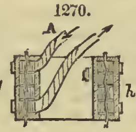


1266.



1271.

1270.



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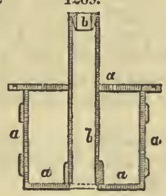

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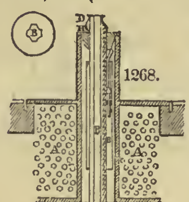

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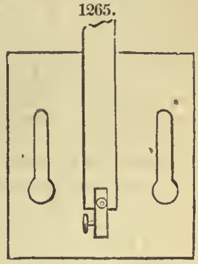
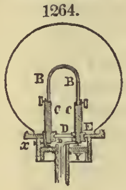
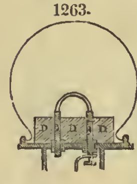


1264.



1263.



nished in the same manner as that shown in Fig. 1259, and before described. The weight of the shaft B E is rather overbalanced by the weight Q, which is attached by a string passing over a pulley R to B. A pinion F works into the rack E, and fits it loosely with a back lash of about a tenth of an inch. The pinion F is connected with an ordinary train of multiplying wheel-work (concealed behind the brass plate c''') and terminating by any well-known sort of fly or escapement motion of such kind, that F Y will be prevented from revolving quickly, but will at the same time yield with a slow motion to any slight force from the rack E, so as to prevent the rack E from moving up or down too quickly. The negative wire from the galvanic battery is connected with one end of the helix coil A, and the other end of it is soldered to the brass case, so that the current passes through the helix wire to its case, and thence by means of the springs D which are fixed to the case, and are in contact with the iron cylinder B, up the shaft D E, to the electrode M, whence it flows through N, down K, and returns to the positive pole of the battery, by means of the wire y. But when the current thus passes the helix, A causes the shaft B to be drawn downwards, which motion separates the two electrodes M N, and light is evolved until the electrodes become too far separated, when the current suddenly ceases, the light becomes extinguished, and the helix ceases to draw B downwards, when the weight Q begins to draw it upwards again, until the electrodes touch one another, whereby the electric current is re-established, and the light is repeated as before.

The apparatus which has been described, Fig. 1267, may be modified in manner following: Fix a regulating coil with a properly weighted iron centre, &c., just like that described in Fig. 1259, (at R, o,

p, x, y.) This coil is fixed to *c*, Fig. 1267, and its wire is permanently included in the electric current and O, instead of P, moving a ratchet V V; when it drops, it presses a spring or lever in connection with the negative wire from the battery in contact with the shaft B, so that most of the electric current passes from the negative wire through the lever to B direct, and B is no longer drawn down by the action of A, but begins to rise by the force of the weight Q, which in this modification of the apparatus is made to overbalance the shaft as it does in Fig. 1267.

The apparatus employed, Fig. 1267, in any of the preceding modifications may be made to act by substituting the arrangement shown in Fig. 1268, for the parts A and B, which gives a greater moving power, and allows the electrode shaft to move through a long space not limited by the length of the coil A. A′, Fig. 1268, is a helix coil, similar in construction to A, but differing in form, as is indicated in the sectional view, Fig. 1268. A short hollow cylinder B′ is substituted for B; a brass rod B″ (or a bar "feather edged," for the sake of lightness) passes freely through B′, and ratchet teeth are cut in it as shown, by which a spring ratchet *g* suspends B′, in the position shown in the engraving. An end H, which screws on to the top of the central tube of the coil A, carries the conducting springs D D, and guides the shaft B″; when the shaft B″ rises (carrying B′ with it) it brings the projecting end of the ratchet *g* against the slanting side of H, the pressure of which pushes the ratchet out of the teeth and lets B′ descend for the space of one notch or tooth, so that B′ is always ready when the current in A′ acts to draw the shaft B″ a fraction of an inch lower, and yet does not prevent the shaft from gradually moving upwards to any extent to supply the waste of the electrode, while B′ never follows the shaft higher than H.

The helix coil last described, Fig. 1268, may have its action on B′ augmented by making certain parts of the case in which the coil is wound, to be of soft iron in place of brass, as shown by the section of the case in Fig. 1269, the parts marked *a* being iron, and those *b* brass.

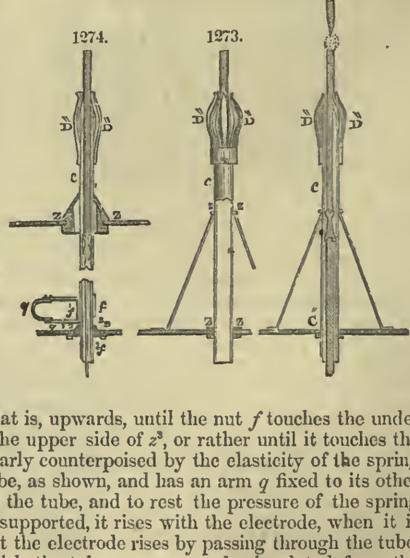
An electro-magnet may be used in place of the helix coil surrounding the moving piece of iron B^1; the poles of the electro-magnet being presented obliquely or directly beneath B^1, the form being altered so as to be the better suited to be attracted by both poles of the electro-magnet.

Reflectors may be adapted to electric lighthouse lamps as well as to electric lamps of all sorts.

The intensity of the electric current (whatever may be the nature of the lamp or apparatus used for producing the light) is effected by including in the electric circuit a long coil of insulated copper ribbon wound in an iron case, as shown in section, Fig. 1270, and part side view with cover removed at Fig. 1271. The coil may be made in pieces separately wound on, and their ends joined in succession, the two extreme ends A *e* of the first and last coils being made to pass through the holes *p q* in the case. A hollow cylinder of iron, or a number of bits of flat iron bar *g h*, are placed around the coil like the staves of a cask, and are held together by elastic bands of vulcanized caoutchouc. A good proportion for the substance of the coil is one-hundredth of a square inch of copper in section to every 40 yards of length. The ends of each coil are held from slipping back or unwinding, while the next coil is being wound, by being bent round and backwards over a pin K K′, screwed into the side of the iron case. The numbers annexed to the arrows indicate the succession of the different portions of the coil on which they are placed. The letters A B C D E indicate the commencement of each of the coils, and *a b c d e* their several terminations.

The solid electrodes employed in electric lamps in supporting tubes, are represented in Figs. 1272, 1273, and 1274. A tube *e*, serves to guard the electrodes, to hold them steady, and to conduct the electricity freely up to the top part of the electrode, the current being passed into the tube through the sole-plate *c*″, which is put in metallic connection with the negative wire. D″ D″ (Figs. 1272, 1273, and 1274) are spring conductors (they may be of iron) fixed on the tube *e*, the tips of which embrace the electrode near the point where the light is developed. The electricity has by this means a free passage from the tube into the electrode. The tube may be fixed mechanically to the framework *c c*″, and yet insulated electrically from it, as shown in Fig. 1273, by means of collars of dry hard wood *z z*, on the same principle as the legs of the upper electrode-stand K, are insulated from the sole-plate *c*″.

1274. 1273. 1272

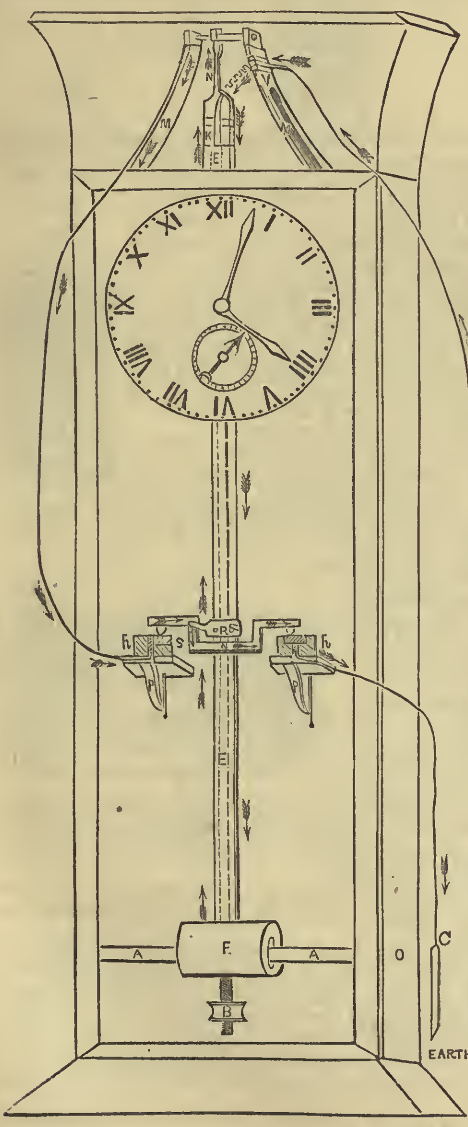


The electrode may be composed of many pieces slightly joined together, end to end, and placed in a tube, Fig. 1274, of any required length. To obviate the necessity of joining the parts firmly, the following arrangement, Fig. 1274, has been contrived, wherein the electrodes need never be drawn backwards in the tube: *c*″ is a piece of the supporting framework of the lamp, made for the purpose of holding the tube steady. The tube has a free sliding motion for a short space, that is, upwards, until the nut *f* touches the under side of z^3, and downwards, until the collar f^1 touches the upper side of z^3, or rather until it touches the part *q* which rests on z^3. The weight of the tube is nearly counterpoised by the elasticity of the spring *q*′, which is attached to an arm projecting from the tube, as shown, and has an arm *q* fixed to its other end, the further end *q* being forked so as to embrace the tube, and to rest the pressure of the spring upon the top of z^3. The weight of the tube being thus supported, it rises with the electrode, when it is pushed upwards by E^1, until *f* touches z^3, and after that the electrode rises by passing through the tube.

The parts of the fixed supports *c* and *c*″, through which the tube passes, may be insulated from the rest of the framework by collars of wood, as represented by z^2 and z^3.

The following are improved modes of preparing the materials for electrodes: take the powder of various carbonaceous matters, which make electrodes of different qualities as to illuminating power and resistance to abrasion by the electric current. The materials preferred are; first, plumbago powder, having its iron, &c., extracted by washing and warming in acids; second, lamp-black; third, charcoal powder of sundry kinds of wood; fourth, the powder of the carbonaceous concrete which becomes deposited in gas retorts; or, fifth, grains of this latter substance sifted so as to obtain a somewhat uniform size of grain: any one of these materials mixed with a quantity of brown sugar, in such proportions as are requisite to form a free paste with the powder when the mixture is melted by heat, a much larger proportion being sometimes employed for making the product cohere better. This mixture is melted and boiled (without water) until it becomes stiff; it is then pressed (while hot) into iron moulds of suitable shapes, the inside being lined with paper, or chalk, or plaster of Paris, to prevent the mixture from adhering to the mould, and to form a porous envelope through which the gases, &c., can slowly escape. The moulds have numerous small crevices or holes for the purpose of letting the gases and steam escape from the material when baked. The moulds when charged and closed tightly are heated very gradually, so as to allow sufficient time for drying and dispelling the gases without their destroying the compactness of the material. When a red heat is thus obtained, it is after a time allowed to subside, when the contents of the moulds are carefully taken out and placed upright in a crucible, which is filled with sand luted down and gradually raised to a white heat. At this high temperature they may be kept for some time, to give them greater mechanical hardness and strength; they are then covered up and allowed to cool gently, and being cleaned if they retain a coating of any other substance, they are put into close-fitting tin cases for use.

1275.



ELECTRIC CLOCK. Fig. 1275 is a view of the electric clock in the telegraph office of the Eastern Counties Railway, Eng. C Z are plates of copper and zinc buried in the earth (with a quantity of coke) a depth of nine feet; this is termed an earth battery It is computed that the electricity derived from the earth with the two plates is sufficient to work thirty clocks, and will last a number of years without being disturbed; E E the pendulum, made of wood, to the lower end of which is fastened a coil of wire enclosed in a brass case F; A A are two permanent magnets; B the balance weight for regulating the pendulum; M M a stand supporting N a steel spring by which the pendulum is suspended; K a spring to which the wire coming from *z* is attached; V a piece of wood for insulating the wire from the stand; *h h* two small pieces of wood; *t t* two metal pins passing through the wood *h h*, one of the pins *t* is joined to a brass plate, the other pin has a small gold head, brought level with a piece of agate S; *n* the break for making and breaking the contact; R two arms projecting from the pendulum; *p p* brackets supporting *h h;* suppose the pendulum is set in motion by moving it to the left, one of the arms R would be brought in contact with the break, pushing the point which did rest on the agate S on to the metal *t*, the other end of the break would still rest on the brass plate; the current of electricity would then pass from *z* up the wire (as indicated by the arrows) to the spring K, (down one of the wires at the back of the pendulum shown dotted,) through the coil in box F up the other wire to spring N, then down the wire to pin *t* along the break to the other pin, and terminating at C, the circuit would then be complete; when in the position described, the coil F would become a magnet, and be attracted back by the magnet A, the other arm would then push the break on the agate, the pendulum would then

fall back again, making the contact, thus a constant motion of the pendulum is kept up. To complete the clock, a few wheels are necessary for the proper working of the hour, minute, and second hands.

ELECTRO-METALLURGY. Electro-metallurgy, depending essentially on galvanic agency, is subject to the operation of the same principles, and governed by the same laws laid down in the books which treat of galvanism and galvanic batteries; the successful reduction, therefore, of the metals, must depend entirely upon a thorough knowledge of galvanism, and galvanic apparatus.

Independently, however, of these general galvanic properties, there are certain particular ones appertaining either to the different metals, or to the different qualites of the same metals, which have to be considered in detail, as well as the apparatus to be employed for precipitations.

The substance best adapted for the complete separation of the solutions, in a single-cell apparatus, is animal membrane. Of this there are various kinds; bladders of different textures, the lining membrane of the intestine of the ox, fine gold-beaters' skin, or bladders of various animals may be used. Animal membrane separates solutions better than any other diaphragm, but, for most purposes, it affords too much resistance to the passage of the current. Brown paper, and cartridge-paper, are frequently of value for the electro-metallurgist, and they last for a considerable period without renewal. Of late, earthenware tubes have been very extensively employed.

The following is the order in which different substances stand with regard to their capabilities of admitting the passage of electricity:

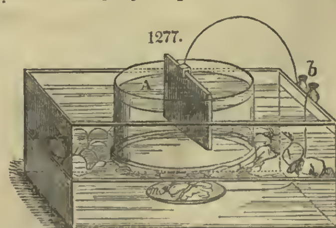
Brown paper,	Bladders of various thickness,
Thin plaster of Paris,	Thick plaster of Paris,
Porous earthenware,	Capillary tube.
Gold-beaters' skin,	

Of the various forms of apparatus, which may be used for the precipitation of the metals, the most simple is that having a porous earthenware tube, to contain the acid and zinc, whilst the negative metal, which is usually a mould, is placed externally to this, and connected by a piece of wire to the zinc. Thus, for instance, take a pound pot, Fig. 1276, and half fill it with a solution of sulphate of copper, S; in this, place the earthen vessel P, with the dilute acid A and zinc Z, and this constitutes the whole of the present form of apparatus; for, when we desire to make an electro-medallion, it is only necessary to place one or more casts in the outer vessel *m m* connected by a wire with the zinc, and then action will immediately commence. Any number of moulds may be placed in the outer vessel, provided they can radiate to the zinc. Saturation of the liquid may be preserved by suspending some of the salt in a linen bag over the mould. This form is objectionable, because the salt of zinc speedily passes through to the outer vessel; but it has the advantage of allowing the mould to be placed vertically, in which position it is much less liable to have particles of dust settling upon it. There is no limit to the size of this outer vessel; for a water-butt, a tank, or even a lake naturally impregnated with sulphate of copper, would answer.

1276.

There is another form, where bladder takes the place of the earthen vessel, and where the position of the cast is horizontal. Here, the outer vessel, Fig. 1277, which is square, is made of wood, coated internally with cement; on one part of the edge of which, a piece of brass *b* is fixed in which are two holes, one for connection with the wire of the cast *m*, the other with that of the zinc. In the interior of the trough, a moveable shelf of mahogany is placed, on which is supported a glass containing a zinc plate Z and crystals of sulphate of copper to be dissolved. The glass has a piece of bladder tied over the rim, and this forms an outer vessel similar to the porous tube in the former apparatus. It, in like manner, contains the acid and zinc; the latter being connected by a screw to a wire, in such a way that it can be readily removed.

1277.



In every single-cell apparatus, the solution of metallic salt should be maintained in the required degree of concentration, by keeping some crystals of the salt undissolved in the solution. If these crystals are allowed to sink to the bottom of the vessel, they will not answer the intended purpose of maintaining a saturated solution; for the portions of the fluid which have been deprived of their metallic salt rise to the surface, whilst the saturated parts remain in contact with the crystals at the bottom, thus preventing their solution. This difficulty may, however, be readily overcome, by placing the crystals to be dissolved in a little bag, on a shelf at the top of the liquid, by which means the saturation of the fluid will be ensured.

The only circumstance to be observed is, that the zinc be equidistant at every place from the metal on which the reduction of the new metal is to be effected, so that the deposite may be everywhere equally thick.

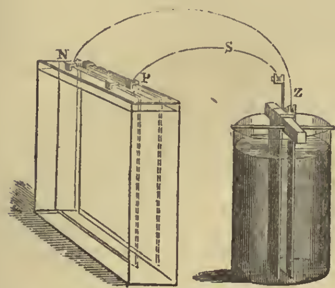
There are other metals besides zinc and iron that might be used to generate electricity: thus, lead will reduce copper, silver, gold, and various other metals. When it is employed for electro-metallurgical experiments we must form a soluble salt, of which the acetate and nitrate are most conspicuous. If we use nitrate of potash in the outer side with the lead, and a solution of metallic salt, say of copper, in the inner side, with the negative plate, the reduction will take place. It is vain to attempt to reduce a sulphate by this salt, for the sulphate of lead is absolutely insoluble. Its equivalent number is very high, one hundred and four of lead being equal to thirty-two of zinc, which is one serious objection to its use.

Tin may be used to generate electricity, it being soluble in muriatic, sulphuric, acetic, oxalic acids &c. It has a feeble force, requires a large plate, and thin porous tube. It is best used with dilute sulphuric acid on one side, and the metallic salt, which should be a sulphate, on the other. It reduces

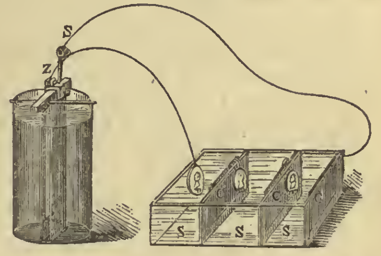
several metals, but, unfortunately, has a high combining number, requiring fifty-eight grains to generate as much power as thirty-two grains of zinc.

A solution of a salt of copper is to be placed in a convenient vessel, Fig. 1278, and the object N, on which the precipitation is to take place, is to be connected with the zinc of the battery Z, whilst a piece of sheet copper is connected with the silver S. As soon as action commences, water is decomposed, oxygen passes to the copper pole and oxydizes it, and the hydrogen passes to the negative plate. Whilst the decomposition is taking place, oxide of copper is passing to the negative pole, and the acid to the positive pole; the hydrogen reduces the oxide of copper at the negative plate, whilst the acid combines with oxide of copper at the positive end, and thus the saturation is continued.

1278.



1279.



A series of precipitating troughs, arranged like a compound battery, may be employed occasionally with only one battery. In this case, we should have one generating cell in the battery, and six, eight, or ten decomposition cells; therefore, by the fundamental laws to which the action of the galvanic fluid is obedient, we should have six, eight, or ten equivalents of metal reduced for one equivalent of zinc. Theoretically, this apparatus, Fig. 1279, exceeds every other in economy—practically, it has not been so much employed as it ought to be, particularly in the reduction of plain copper plates. The galvanic series is made by alternating the metal C to be dissolved with the object *m* to receive the precipitate, the last mould being joined to the zinc Z of the battery, and the last copper with the silver S; the positive plates should be large, and the liquid rendered as conducting as possible to lessen resistance. It is important in this apparatus that every positive and negative plate should possess nearly the same surface, and the solution the same strength, in order that the metal of the same quality should be reduced in each cell.

Description of Fig. 1280.—A, the battery cell, extending downwards 2 feet under the floor, and terminating in a point, in which a stop-cock is fixed, to draw off the saturated solution of sulphate of zinc, which is formed there. The bottom is reached by a trap-door and steps.

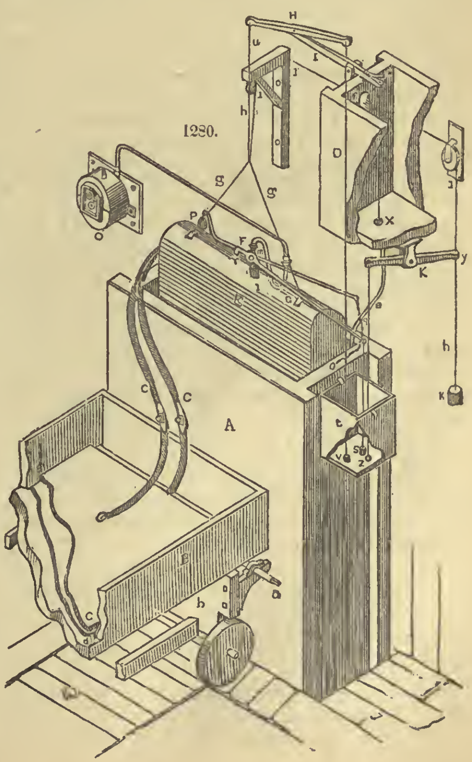
B, the decomposing trough, resting on a keel, which, for the purpose of agitating the solution, enables a rocking motion to be given to the trough, by means of a coupling shaft *a* connected with the truck *b* on which the trough is moved to any part of the room, for cleaning or changing the plate.

C C, conductors from the battery plates, each formed of five lengths of copper wire 1-10th of an inch in diameter, twisted together, and covered with water-proof tape, the one leading to the positive or dissolving plate *c*, the other to the negative or receiving plate *d*, the latter being placed on a board, with small feet or wedges, to keep it at the proper distance from, and parallel to, the positive plate.

D, a water-tight box containing a solution of sulphuric acid in the proportion of 1 to 4 water, by which the battery cell (having been originally charged with solution of the requisite strength, 1 to 30) is constantly supplied with renewed acid, through a lead pipe *e* which extends downwards into the cell about 2 feet, and is turned horizontally so as to cause a circulating movement in the solution. The box is provided with a float *f* to indicate the height of the acid solution in it, and the quantity which has passed into the battery.

In Fig. 1280 the acid box is placed near the battery cell for the sake of bringing it within the margin lines. It is nearly close to the ceiling, in

1280.



reality, so as to afford by its height a considerable force to the solution issuing from the pipe, that i may circulate freely around the battery plates.

For want of height in this Figure, it has also been necessary to omit a beam which passes along the side of the room nearly close to the ceiling, on which a small carriage and pulley travel, for the purpose of raising the plates and moving them to any part of the battery range.

E, a gasometer, or gas collector, formed of thin copper, suspended by the wires *g* and the cord *h*, which passes over the pulleys *i i i*, and terminates in a counterpoise *k*, intended to balance in part the collector. which is placed immediately over the plates in the battery, and dips into the solution. It is furnished with a stop-cock *l*, through which the gas passes by the flexible tube *m* and copper pipe *n* to a gas meter *o*.

F G, levers—the former, F, being attached to the plug of the stop-cock, having at one end a weight *p* and at the other a chain *q* fastened to the battery cell; the latter, G, turning in the same centre, and brought by a screw *r* at one end into contact with the under part of the former, F, and kept in contact with it by the pressing of the weight *p*. To its other end a small block of wood *s* is attached, dipping into a waste-box *t*, and acting as a weight when the box *t* is empty, and as a float when the box is filled by overflow from the battery cell.

H I, levers, drawn downwards by the weight of the collector, with which they are connected by the cord *u*. The former, H, turns on a pivot at the end of the latter, having at its other end a cord carrying a weight *v* which acts in the same manner as *s;* the latter, I, carrying, as before mentioned, the lever H at one end, and having at the other end a spring *w* screwed to it, from which a wire, passing through the lever, descends to the valve *x* for the purpose of raising the valve suddenly, being first closed upon the lever, until the adhesion of the valve to its seat is overcome, when the spring returns to its former position with a jerk, carrying up the valve, and opening the aperture at once to its greatest extent.

K, a lever fixed to the bottom of the box D, having at one end a small hole through which the cord *l* passes, until checked by a knob *y*, when the other end rises and lifts a valve *z* in the bottom of the box *t*.

Working of the apparatus.—The operation proceeds in the following manner. The aperture of the stop-cock *l* must be so adjusted by the screw *r* as to allow the gas evolved from the plates of the battery to escape at the same rate as that at which it is generated, allowing a slight excess to resist the uncounterpoised portion of the weight of the collector, or its tendency to sink down. Then, when the quantity evolved is greater than can pass through the aperture, the collector will ascend till the lever F is restrained by the chain *q*, when the aperture will be enlarged till equivalent to the quantity evolved. On the contrary, when the quantity evolved is less than that for which the adjustment has been made, the collector will descend and pull down the levers H and I; the weight *v* will resist the end of the lever H, and the end of the lever I carrying the spring *w* will rise, and with it the valve *x* of the acid cistern, with a jerk; a quantity of the strong acid solution will then rush into the battery cell by the pipe *e*, with sufficient force to circulate round the plates, displacing a portion of the lighter or less acid solution, which will run off by the overflow pipe *o* into the box *t*, which thus becomes a measure of the quantity of acid thrown into the cell. When the lever H then becomes released from the weight of the float *v*, the acid valve *x* preponderates, falls into its seat, and stops the supply. At the same time, the lever G of the collector is also released by the floating of the weight *z*, and the aperture of the stop-cock completely closed by the weight *p*. The gas collector in this condition rises rapidly, till the knob *y* comes into contact with the lever K, when the valve *z* opens, and the solution in the waste-box *t* runs into a vessel placed for its reception, where its deficiency of acid is supplied, and it again returned to the cistern D. The waste-box *t* being emptied, the floats *s* and *v* again descend to the bottom of the box *s*, carrying down the lever G, by which the aperture of the stop-cock is opened, and the apparatus is again in a position to throw in a greater supply of acid, if the energy of the battery is not sufficient to evolve the quantity of hydrogen for which the aperture has been adjusted. Thus the *power* of the battery depends on the stop-cock, whose normal position is adjusted in the first instance to the required openness by the screw *r;* and the state *of its working* is ascertained by the quantities of gas which pass through the meter in equal times.

The voltaic deposite of metal may take place upon any conducting substance, which is capable of acting the part of the negative metal, in the arrangement. The laws which relate to this, are the same which regulate, in a similar manner, the plates of the battery. The deposite may be effected upon most metals, except the earthy and alkaline, and upon any alloy or compound of them. It may, likewise, take place upon charcoal and plumbago.

The following is a short list of substances which may be used to receive the deposite of metal:

Carbon	In all metallic solutions, acid, neutral, or alkaline.			Lead	In all alkaline, in all but the preceding, saline and acid.		
Platinum.........	do.	do.	do.	Bismuth..........	do.	do.	do.
Gold...............	do.	do.	do	Antimony	do.	do.	do.
Palladium	do.	do.	do.	Tin................	do.	do.	do.
Silver.............	In all alkaline, in all but the preceding, saline and acid.			Iron	do.	do.	do.
				Zinc	In some alkaline		do
Copper	do.	do.	do.				

Non-metallic substances.

Sealing-wax	In all saline or acid solutions; not in alkaline.		
White wax	do.	do.	do.
Beeswax and rosin	do.	do.	do.
Stearine	do.	do.	do.
Spermaceti	do.	do.	do.
Plaster of Paris, prepared	do.	do.	do.
Some animal substances	do.	do.	do.
Most vegetable substances	do.	do.	do

Now by the preceding table we perceive that some substances may be immersed in one solution with impunity, while others would be destroyed by its action on them. It is, therefore, important to know, when we have a substance which is acted upon by any metallic solution, how to make a reverse from it that shall not be injured. For convenience a table is appended, showing at one view the modes of preparing moulds of different substances. The perpendicular row is a list of the objects to be copied, the horizontal the means of multiplying them. Suppose the operator had a valuable silver medal, of which he was desirous of making a fac-simile, he would look in the table against silver, and would there find that he could make a mould, or reverse, in copper, by electro-metallurgy; but to this he would doubtless object. He would then see by what other methods he could also make a mould, and he would find that he could succeed with each of the processes given, and perhaps he would prefer plaster of Paris, as least likely to be injurious to his medal. Having made the mould in plaster, he would see from the former table, that when prepared it might be placed in any saline or acid solution of copper, to form the fac-simile.

LIST OF THE PRINCIPAL MODES OF MAKING MOULDS OR REVERSES OF VARIOUS OBJECTS.

METALS.	COPPER.	LEAD.	ALLOYS OF LEAD.	SEALING-WAX.	STEARINE, SPERMACETI, WAX AND COMPOUNDS.	SULPHUR.	PLASTER OF PARIS.
Copper	by Electro-Metallurgy.	by percussion, rolling.	by clichée.	by fusion.	by fusion.	by fusion.	by mixture with water.
Silver	do.	do.	do.	do.	do.	do.	do.
Gold	do.	do.	do.	do.	do.	do.	do.
Platinum	do.	do.	do.	do.	do.	do.	do.
Lead	do.	..	do.	do.	do.	..	do.
Alloys of	do.	..	by clichée.	do.	do.	..	do.
Tin	do.	..	..	do.	do.	..	do.
Iron	do. by Percussion.	by percussion, rolling.	by clichée.	do.	do.	by fusion.	do.
Other Metals	by Electro-Metallurgy.	..	..	do.	do.	..	do.
Sealing-Wax	do.	by percussion.	..	..	do.	..	do.
Beeswax and Compounds	do.	..	..	..	..	..	do.
Stearine	do.	..	..	..	..	..	do.
Spermaceti	do.	..	..	..	..	..	do.
Sulphur	..	..	by clichée.	..	by fusion.	by fusion.	do.
Bread-crumbs	..	..	..	by fusion.	..	..	do.
Plaster of Paris	by Electro-Metallurgy.	..	by clichée.	..	by fusion.	by fusion.	do.
Glue and whitening	not.	..	do.	..	do.	..	do.
Animal subs	by Electro-Metallurgy.	..	some by clichée.	some by fusion.	do.	by fusion.	do.
Vegetable sub	do.	..	do.	do.	do.	do.	do.
Gum	..	..	..	..	..	..	do.
Isinglass	..	..	..	..	..	..	do.
Siliceous bodies, as Glass	by Electro-Metallurgy.	..	by clichée.	by fusion.	by fusion.	by fusion.	do.
Aluminous do	do.	..	do.	do.	do.	do.	do.

Carbon, from its cheapness, from its indestructible nature, and from its being unaltered in all metallic solutions, is invaluable for electro-metallurgy. One variety of it, graphite, or plumbago, usually called black-lead, has a most extensive application, which we shall hereafter have occasion more especially to describe.

Platinum, from its being unaltered by any solution, holds an important place for the reception of every metal; its great price, however, must always be an impediment to its general use.

Gold is equally valuable with platinum, but is still more expensive; yet when extended to that state in which it exists as gold-leaf, it may be applied over the surface of any soft substance, and thus a metallic surface is presented. This plan may be employed with other metals, such as silver or tin; but we have other methods which render all these modes unnecessary.

Silver only reduces gold, platinum, palladium, and two or three more metals from these acid solutions, and therefore may be employed as a negative one for the reduction of metals. Silver-leaf of a thickness of about one square foot to the ounce, and made of pure metal, is much used by the forgers. The process they adopt is, to place the coin to be copied on a piece of wood, and upon the coin they place a piece of this thin silver. They beat it gently with a wooden mallet, till a perfect impression is taken on the metal, a result soon obtained. They then copy the opposite side of the coin in the same way. The two impressions are then soldered together, and the manufacturer sallies forth and risks his neck for the illicit shilling which has cost him this labor. The reader will doubtless have no inclination to practice this fraud, and, therefore, it is unnecessary to enter further into the process; but it should be borne in mind, that the same means may be employed with a better intention by the electro-metallurgist, to obtain a mould.

We have now to treat of the alloys of lead, tin, bismuth, antimony, and zinc, which demand especial attention, because there are means of casting these alloys, and of making reverses, moulds, and medals, by more ready methods than we possess for any other metals. It has been remarked that these alloys have melting properties, not only below the mean of the melting points of the respective metals which compose them, but even some of them considerably below the fusing point of the most fusible metal that enters into their composition. To some of these alloys we owe the manufacture of type, to others the process of stereotyping, to others that of polytyping or clichée. The composition of the type-metal is stated to be 1 part of lead to 16 of antimony, and sometimes a portion of copper is added; this

portion probably varies at each foundry; as they generally consider that part of the business a secret Other compositions are given, as 6 to 2, 4 to 5, or 4 to 1 of antimony to lead. In the foundry there are a number of crucibles, each heated by a charcoal fire, one being allowed to each workman. To make a type, the operator takes a little of the melted alloy in a small ladle each time, and pours it into the mould which has the counterpart of the letter he wishes to make. The moment it is in the mould, he carries it suddenly upwards with a jerk, above his head, by which means the metal is forced into all the fine parts of the work, and a good impression is insured. Now we might expect that those who day by day work at this occupation, would attain to certainty in their proceedings; but this is by no means found to be the case, for they form a very large number of imperfect types which are obliged to be remelted. I give this process to show that with those about to be detailed a strong analogy to coining is presented. In the first case, it is with a fluid, or semi-fluid, metal; in the last with a solid mass. The alloys which may be used for these purposes are very various, according to the object from which we desire to obtain a reverse, for as a great latitude is allowed in the fusing point, so at one time we prefer the more fusible, at another that which melts at a higher temperature.

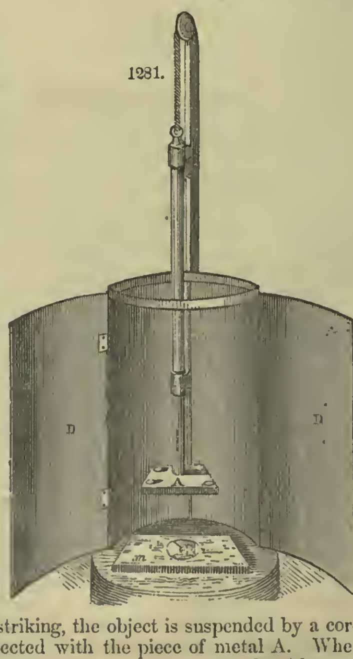
The following is a list of alloys which are employed by various authors, to which should be added all the compositions of type-metal last described, and as antimony possesses the property of expanding in the act of cooling, its alloys are well adapted for casting.

	Tin.	Lead.	Bismuth.	Zinc.		Tin.	Lead.	Bismuth.	Zinc.	
1	4	1	0	0	5	3	5	8	0	fuses about 212° Fah.
2	5	10	1	0	6	1	1	2	0	said to fuse at Fah. 200.
3	0	1	1	0	7	1	2	3	0	do. 200.
4	1	1	0	0	8	1	0	1	1	do. 200.

All these compounds are used at a point between the fluid and the solid state, for at that heat they assume a pasty appearance, which is probably caused by the alloy consisting of two parts, one more fusible than the other. In fact, if we examine the mass very attentively, it appears to be composed of a quantity of perfectly solid metal in a fine state of division suspended in another portion of alloy perfectly fluid. Having obtained our alloy in this state, it is ready for the process of making our reverse, and this process is termed the clichée. The alloy marked 1, 2, 3, 4, as well as the compositions for type-metal, will answer for iron, brass, copper, or other hard substances; perhaps No. 2 and No. 3 will be found, after type-metal, entitled to the preference. When we desire to clichée from wood, sulphur, or from another clichée, we must employ those alloys which fuse more readily, and Nos. 5, 6, 7, and 8 come into use. If hard metals are used from which to clichée, we should take care to clean them thoroughly before using, and always employ them in a cool state. In using one clichée for making a second, we must take care to employ a less fusible alloy for the first than for the second; thus the type-metal and Nos. 1, 2, 3, 4, answer as a primary mould to make casts in 5, 6, 7, 8. To clichée from plaster of Paris, the material must be prepared either by linseed oil, gum, or gelatine, which processes will be described when treating of those substances, and sulphur moulds must be employed within a few hours of their manufacture.

The simplest mode of making a clichée is to pour a little of the fused alloy on any flat surface, then to skim it clear with the edge of a card that the surface may be most perfectly bright, after which we should wait till it is nearly at the point of cooling, when with a considerable jerk the matrix is to be brought down upon the alloy, by which operation the fluid part will be forced out in all directions, and a reverse, equal in polish, sharpness, and beauty to the original, will be instantly obtained. If the alloy is used too hot, the surface is apt to present a crystalline appearance; it is therefore very important that the object should be cool enough to make the alloy perfectly hard, as soon as the blow has driven the metal into all the finest lines. When taking a clichée from an intaglio the air has not always time to get away, in which case little holes or bubbles are very apt to be caused. The surplus metal round the edges of the mould so formed is then trimmed off in a lathe; but this operation is generally unnecessary for electro-metallurgy.

1281.

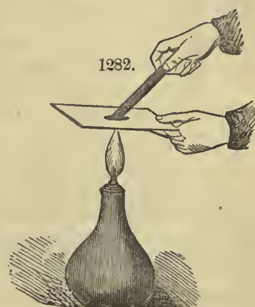


The Italians have a method of taking very perfect moulds with these alloys. They take a portion of the melted mass, and place it on a piece of paper; upon this they lay the medal, and under both a piece of carpet; upon the medal they place a log of wood, and then a sharp blow on the wood will ensure the sharpness of the cast. The worth of a cast thus made, is from sixpence to half-a-crown. I have before mentioned that clichée is nothing but a process of coining, and sometimes a sort of coining-press is used for these purposes; the medal or other object is fixed either by mastic or by screws on a piece of metal A, Fig. 1281, which descends with force on the semi-fluid alloy. Previously to the operation of striking, the object is suspended by a cord passing through a ring, and attached to the rod of iron connected with the piece of metal A. When every thing is ready, the doors are shut and the cord let loose, which allows the object to fall with great force on the metal.

An impression may be given to a perfectly clean bright surface of sheet-lead, by placing upon it the object to be copied, and then with a steady hand dealing a heavy blow. By this mode even a sealing-wax impression may be copied, although this, at first sight, would appear hardly credible. By pressure alone, it would be difficult to obtain the result which can be given by the blow. Rolled lead, first scraped, in order to remove any oxide from the surface, and then flattened by running it through a press upon a polished iron plate, will readily take the impression of the most delicate work or engraving. The object to be copied is simply to be placed upon the lead, and then the two are to be sent once, and once only, through the printing-press, as in the ordinary operation for taking a print. The pressure in rolling is far greater than can be given by direct pressure, though there are instruments used by embossers capable of exerting great power. The disadvantage of forming moulds by rolling is a liability of distortion of the image from imperfect stretching of the metal.

Non-conducting substances are of three kinds: substances having no affinity either for the metal or the solution; substances acted upon by the solution; and, lastly, substances capable of combining with the metal thrown down. Those of the first class are by far the most valuable, but are not very numerous. The best of these is sealing-wax—a composition of shell-lac, Venice turpentine, and coloring matter. Dr. Ure gives, as the proportion in which these are used, four, one, and three. The manufacturers have several varieties, the most expensive of which is the best for making seals. Some of them are extremely hard, as for example, a black wax which is used for filling up the letters in the engraved plates of shop windows; but I do not know how a difference of composition can affect the properties of the wax in this important manner. The use of sealing-wax is attended with considerable expense, as good wax cannot be purchased under three and sixpence or four shillings a pound, but it takes impressions of objects of the greatest delicacy with the utmost accuracy. Every one uses this substance, and sealing is one of those operations in which every one thinks that he excels his neighbor in the manner in which he performs it; but, however well satisfied he may be with his skill in the small way, yet the management of large seals is attended with great difficulty and uncertainty. Proof-seals are made by engravers, by holding a piece of card over a flame, and rubbing, gradually, a stick of wax, previously softened by heat, upon the heated card, till a sufficiency is obtained, when the coin is to be pressed upon it. Very large seals are made by taking a good-sized stick of wax, and holding it in a flame, not only till the point, but even three or four inches of its length are lighted. It is then to be held over a piece of paper or card, when large drops of melted wax will keep falling, and in a short period a considerable quantity will be melted. The flame of the stick is to be blown out, and the fluid mass well stirred round and round, till all the air-bubbles are dispersed, and a clear surface of semi-fluid wax is exposed. It is now ready to receive the impression of the object of which we are desirous of obtaining a copy. This is to be laid upon the wax, and pressed with considerable force, and lastly plunged into cold water, so as to cool it suddenly. Much less difficulty attends the use of a metallic die, for that abstracts the heat, and does not adhere. The accuracy with which sealing-wax takes impressions with care, is shown by its copying the lines on mother-of-pearl, and analogous substances which naturally possess the property of decomposing the rays of light; and the same colors which exist in the original are also to be observed in the copy.

1282.



When we are desirous to obtain an impression in wax from wood or similar substances, they should be previously brushed over with a little salad oil. In these cases, by plunging the wax into cold water, its surface is apt to sink in places, and thus becomes uneven. Very large seals have been made of sealing-wax, by means of placing the mould on the semi-fluid composition, and subjecting it to hydrostatic pressure.

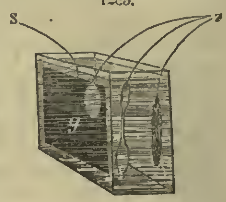
White wax may be used for taking casts, and can be procured with least expenso by buying the waste ends of wax candles, which may be readily melted over a lamp. The object to be copied is to be very lightly oiled with a hog's-bristle brush previously dipped in that fluid. A moment's exposure of the medal to a current of steam, or even to the breath, will answer the same purpose, because a film of water, for which wax has no affinity, covers the medal, and therefore causes a separation between the wax and the metal.

Electro-gilding, Plating, &c.—The infilming of one metal by another is a subject of much interest, and the process has received different names according to the metal employed for that purpose. Thus, when gold is used, it is termed gilding; when copper, coppering; silver, silvering, or plating, &c. In every one of these cases we have to be careful that the two metals adhere, and for this purpose we take means to prevent any film of air, oxide, or any non-conducting substance, from remaining on the first plate, as that would cause a separation between the metals. We apply heat, we scour the plate, or where it is possible, we slightly act upon the surface of the metal to receive the new deposite, taking care thoroughly to wash the metal after this operation.

Electro-gilding is, in most cases, remarkably easy, for if care be taken to follow the laws which have been already detailed, it will be attended with very little trouble. The metal to receive the gold may be either platinum, palladium, silver, copper, carbon, gold itself, or indeed almost any other metal, when the auro-cyanide of gold is employed. The surface should be chemically clean, and freed from adherent air, either by plunging it into nitric acid or a solution of potash, or by heating it and then quenching it in acid. The smoother the surface the more favorably the deposite will take place upon it, for a very rough surface is not quite so well adapted for these operations, the hydrogen having a greater tendency to be evolved from it. When the metal to be gilt does not decompose the solution of gold, the solution may be stronger. When, on the contrary, the metal acts upon the solution, it must be weaker. The electrical current must be suited to these varying circumstances, and in general but a feeble current is required.

For all cases of electro-gilding the auro-cyanide of potassium makes by far the best solution. It is scarcely decomposed by any metal. It may be prepared by digesting oxide of gold in a strong solution of cyanide of potassium. For our present purpose, a strong solution of the salt is to be preferred, and, from the corrosive nature of the cyanide of potassium, it should always be placed in a glass vessel. For gilding, the single-battery process will answer every purpose where time is not an object, and is indeed as a general rule to be much preferred; but if great speed is required the compound-battery, made of two, three, or four batteries, must be employed, or more cyanide of potassium must be added to the solution of gold. The size of the battery need never exceed the size of the object to be gilded, though if it be larger it will not be of any material consequence, as a strong obstacle to the passage of the current is situated at the positive gold pole. The positive pole, as a general rule, should consist of a piece of pure gold flattened, and the part exposed to the solution should not exceed the size of the object to receive the deposite.

1283.



Every portion of the object on which we are desirous to have no layer of gold, must be coated with tallow, wax, or any other non-conducting substance, the presence of which will prevent any deposite from taking place on those parts. In this way an object may be coated to any desired limit, or upon any circumscribed parts of its surface, as, for example, drawing or writing thereon. The rapidity of the process may be regulated to the greatest nicety by placing more or less of the positive plate of gold in the solution, by which means, as in other cases, the quantity of electricity passing may be regulated with the utmost precision.

The time occupied for the process must vary according to the amount of electricity passing, and the quantity of gold required to be deposited; but the thickness of the deposite can at any time be learned, either by ascertaining the additional weight it has received, or by the reduction which the positive gold pole has suffered.

To conduct this elegant process with the greatest economy of time, the quantity of electricity should be so regulated to the strength of the metallic solution, that the hydrogen is kept below its point of evolution from the negative plate; for we must always bear in mind that the evolution of hydrogen is attended with evil, as the precipitate will then be in one of the finely-divided states, or even as a black powder.

During the process, particularly if the object have a rough surface, it is a good plan to remove it from the solution before the completion of the process, and rub it with a hard brush and a small quantity of whiting or rottenstone and well wash it; by these means any finely-divided metal will be removed, and the gold will be precipitated in a very even manner. This cleansing is not required when the deposition takes place very slowly from the auro-cyanide of potassium. The color of the gold, if the precipitated layer be very thin, will be a greenish yellow, but when thicker it will be the natural color of the pure metal.

The state of the surface of the reduced gold varies with the rapidity of the process, in relation to the strength of the metallic solution. If reduced very slowly, it will assume the beautiful frosted appearance of dead gold. If deposited more rapidly, the surface will have a brighter appearance. If still more rapidly, the surface will again begin to be brown, and quicker than this the operator must not conduct his process; for then the spongy deposite begins, which the electro-gilder should shun as the very bane of his art.

All objects of silver may be readily gilt in this way, and objects of copper with as great facility as those of silver. Some suppose, and, perhaps, with good truth, that copper articles require less gold than silver ones; the silver, when heated, having the property of taking into itself a certain portion of gold. However, copper is more difficult to bring into a thoroughly clean state than silver, especially in deep crevices. For those cases it is better to plunge the copper article into some acid solution of a metal which it can spontaneously reduce; for instance, into dilute sulphuric acid, containing a trace of either nitrate of silver, chloride of platinum, palladium, or gold, the object of which immersion is not in any way to leave a deposite of the new metal upon it, but thoroughly to cleanse the surface. After this immersion the object may be washed, and as much of the reduced metal as possible rubbed off by means of a hard brush, when it will be found to possess a surface admirably adapted for the reception of the gold.

If we have a number of small articles to gild, we may suspend them in the solution of gold opposite to the positive pole; and especial care must be taken that each part of the object is exposed for the same length of time opposite to, and at the same distance from, the positive pole; for any variation in this respect would cause a different thickness of gold to be deposited. The workman may be well assured, that if any article has an unequal coating of gold, it is owing either to some of the above causes, or that a different relative amount of the positive plate of gold radiated to the various parts of the object.

An imperfect layer of gold betokens imperfection in the cleansing of the object before immersion. Electro-gilding is applicable from the finest platinum wire to any object however large, and no doubt the dome of the Capitol could be gilt as readily as a silver thimble if any person could place it in a proper apparatus.

Whatever be the object to be gilt, it is highly important that every part should be entirely immersed in the liquid, or else that part at the junction of the air and water might be liable to be rapidly dissolved.

The extent to which gold is applied to silver and copper articles is very great, and no variation is required in the process, except in those cases where the object itself may form a decomposition-trough—as silver vases, the bowls of large ladles or spoons, where it is only necessary to fill them with the solution of the auro-cyanide, which in this case should contain no free cyanide of potassium; connecting

them by means of a wire with the zinc of a battery, and inserting a plate of gold in connection with the silver of the battery in the interior of the solution, taking care not to allow the gold and vessel to form a metallic contact; but even in these cases it is far better to immerse them entirely in the liquid, for reasons before stated. All these cases of gilding appear to be rather for appearance and beauty than utility; but sometimes metals are coated for the protection which the coat of gold affords: thus the hair-springs of chronometers have lately been gilt by this process, and patents have been taken out for its application—a circumstance to be more fully considered when treating of the history of electro-metallurgy. The gilding of iron and steel only differs from gilding silver and copper in the necessity to be careful to overcome the difficulty which occurs in most thoroughly cleansing the iron. It should be plunged into dilute sulphuric acid, and allowed to remain for a short time in that fluid before being immersed in the auro-cyanide; and if we wish most thoroughly to protect the metal from the action of extraneous causes, a tolerably thick layer of gold should be used. I am informed that the application of heat to the auro-cyanide favors the adhesion of the metals.

1284.

Sometimes the operator is desirous of having his object bright, either entirely or partially, so that the bright and dead parts may form a contrast with each other. In this case the object is dipped into a solution of soft-soap, to which a little prussic acid is added, thoroughly to cleanse it, when an instrument called a burnisher, *b*, Fig. 1284, which is nothing but a bright piece of steel, the shape of which is suitable to the object to be burnished, is rubbed over it two or three times; and finally the process is completed by a blood-stone *s* fixed upon a handle. The operation of burnishing is generally performed by women; and it is indeed remarkable that they should have learned the use of prussic acid for cleansing gold, which has been employed for many years, especially when we consider that the fact was not known to chemists at the time. It is worthy of remark, that the solution of soft-soap and prussic acid is admirably adapted for cleansing trinkets and all articles of gold when they have become dirty.

The process of gilding by galvanic precipitation from a solution of gold, is very different in its effects from the method formerly patented by Elkington, termed water-gilding; by the latter process the metal which is to be gilt is dissolved in an equivalent proportion to the gold deposited, and therefore as soon as a mere surface of gold is obtained, it has been supposed that no further deposition can take place; but when the gilding is effected by the galvanic battery, any amount of gold may be applied upon the object; a consideration of no small importance, as upon the thickness of the coat must depend the durability of the gilding.

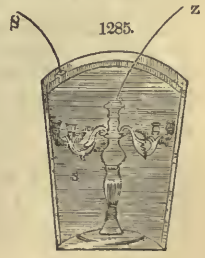
It is not the solution of nitro-muriate of gold which is used for water-gilding, but a solution of the oxide of that metal in potash. The solution may be prepared by adding caustic, potash, or its carbonate, to the ordinary solution of gold, in such proportion that the precipitate first formed is redissolved when it is fit for use. To gild any article, it is plunged, after being first thoroughly cleansed, into the hot solution, and allowed to remain in the solution till a thin coating is obtained, at the expense of a small quantity of silver.

Platinating metals by the galvanic current is a new feature in science. The process is similar in all respects to gilding, but is more difficult. The best solution to be employed is the nitro-muriate of platinum, to which sufficient soda is added to render it neutral. The object to be coated should be smooth, and thoroughly cleansed by potash before the process is commenced. Having proceeded thus far, and the solution of platinum being ready, a fine platinum wire, in connection with the silver of a compound battery, must be placed so as to dip into the solution, but must not be immersed beyond a very short distance. The object to be platinated is now ready for connection with the zinc of the battery; after this is effected it is to be dipped in the solution, Fig. 1285. Immediately oxygen gas will be given off from the platinum wire, in connection with the silver. From the copper or other metal to be platinated, no gas will be evolved, provided too much electricity be not generated. In a few minutes the object will be coated with platinum.

This process must not be confounded with that by which negative metals are prepared for my battery; for in this case the platinum is precipitated of the color and appearance of platinum, but in the latter case it is thrown down as a black powder. The first process I propose to name platinating, in contradistinction to platinizing. To platinize metals we use a strong current to throw down the metal in the black powder; to platinate we may employ solutions of any strength, but we must use more moderate currents, so that the electricity is insufficient for the production of hydrogen.

There is no process at the present time more readily conducted than electro-plating. The best solution which can be used is without doubt the argento-cyanide of potassium. It is generally made by boiling the oxide of silver in a strong solution of cyanuret of potassium. The process which is most favorable is the single battery. The solution should be placed in a glass vessel, and used with a silver positive pole, about the same size as the object to be silvered. The same precautions should be taken and the same measures observed with regard to plating as gilding. The object should be clean, in order that a most perfect adhesion may be effected between the object to be silvered and the reduced metal. The silver will be thrown down in somewhat different states, according to circumstances. If thrown down very slowly, it will assume a beautiful dead appearance; if still more rapidly, it will be brighter. It is, perhaps, as well to use the solution as strong as possible, and take care to stir the liquid occasionally, in order that a proper diffusion of the metallic salt may take place. As a precipitating-trough either the vertical or horizontal may be employed, according to circumstances; the latter is to be preferred for large surfaces, as waiters, and similar objects; in which case a corresponding large plate of silver should be used as the positive pole and placed over the object to be silvered. Sometimes a large circular silver positive pole may be made to surround the object, as in the adjoining wood-cut. The

1285.



silver pole is to be connected with the silver plate of a battery, exposing nearly as much surface as the object to be plated, while the object to be plated is to be connected with the zinc. A little free cyanuret of potassium, added to the argento-cyanide of potassium, hastens the process by increasing the solubility of the positive pole. The quantity of metal reduced can be readily ascertained, either by finding the additional weight of the object receiving the deposited silver, or by ascertaining the deficiency of the positive pole.

Plated articles may be either partially or entirely burnished in the same way as gilt objects, according to the fancy of the operator; and the contrast of dead silver with the bright polished metal much increases the beauty of the object. Copper and its alloy are most readily silvered by this process.

Non-conducting substances can be silvered by first black-leading them, then attaching a wire in such a way as to come in contact with the plumbago. In this case we should be careful to use rather a larger plate of silver than the object, as that favors the growth of the metal, but as a general rule it would be preferable to coat the object first with copper and then silver it.

Electro-plating is of considerable advantage to the operator, for articles may be made entirely of copper, and even finished with laborious minuteness, and then silvered. The probability is, however, that electro-plated articles will not wear quite so well, in proportion to the thickness of the metal, as ordinary plating, for all metals reduced by electricity are found not to resist attrition so well as rolled metals. Electro-plating is a cheap process, independently of the intrinsic value of the silver used.

A pretty application of the art of coppering is suitable to horticulturists, as by its means fruits, vegetables, leaves, seeds, and various other specimens may be coated with copper, either for ornament or for the purpose of illustrating the size, form, and other peculiarities of the object. Apples and pears may be very readily coppered; they are to be brushed over with black-lead, and then a small pin is to be thrust in at the stalk; to this a wire should be attached, which is connected with the zinc of the battery. It may then be placed in the solution, and the whole arrangement completed by the insertion of a piece of copper, which is to be connected with the silver of the battery. In a similar manner cucumbers, gourds, potatoes, carrots, and a hundred other vegetables, seeds, and roots can be covered. Fig. 1286 exhibits a bunch of grapes submitted to the action of the fluid to be electro-coppered. The form, after the process, is characteristic, and marks so strongly the individual character of each variety, that the horticulturist is at no loss to distinguish the specimens at once.

1286.

A beautiful effect of metallic surfaces may be obtained by the deposition of crystallized metal on baskets. The wicker-work must be black-leaded, and connected by means of a wire to the zinc of a galvanic battery; when on being immersed in the metallic solution, and the circuit completed, it will be covered with the most beautiful crystals of copper, sparkling in the light from the facets of thousands of little crystals. It is well to pass a very fine copper wire round several parts of the basket, so that it may touch the black-lead in several places, for this will ensure the coating being more rapidly complete.

In fact there is nothing organic or inorganic which will remain in a solution of salt of copper a few hours, that may not be coated with the metals.

The foregoing electro-coppered objects are trifling compared to the purposes to which electro-coppering has been tried; for actually, experiments have been made to cover the bottoms of ships with that metal.

We present in brief the mode of copying engraved plates in the Coast Survey Office, by Mr. G. Mathiot, who has there devised many of the processes and appliances so successfully employed.

The original on being completed by the engraver, is carefully cleaned, and its surface silvered; it is then washed with an alcoholic solution of iodine, and exposed to the action of light. This process, one of Mr. Mathiot's invention, is beyond question far the best means in use for preventing a final adhesion of the deposite to the matrix plate. The plate thus prepared, is suspended vertically in a vat, containing a solution of sulphate of copper, and a raw copper plate of rather large size suspended parallel to it. These plates are then made to serve as electrodes, by being connected with a powerful battery. The copper in the solution of sulphate, which adjoins the engraved face, is thus deposited by decomposition, being thrown down as a pure copper layer on the face, while the free acid acting on the raw copper-plate thus sustains the strength of the solution; the whole action amounting to a transfer, or carrying by water, of the copper from the rough plate to the engraved surface. When the deposition has progressed far enough to form a good surface layer, the plate is shifted into a horizontal vat of the same solution, and the raw copper plate supported on a frame just above it. A specially contrived furnace sustains in this solution a heat of about 180°, which greatly facilitates deposition. The current is again brought to act and maintained in steady operation until the deposite attains the thickness requisite for safe handling. The plate and deposite are then withdrawn from the solution, filed around their common edge, and the two are then separated or split apart through the iodine layer which is introduced on the original face, forming probably an iodine atmospheric film.

The deposite plate is the alto, which exhibits, in relief and direct, all the engraved reversed lines of the original. This alto is then made to serve in turn as a matrix, on which a new copper-plate one-eighth of an inch thick, is deposited in precisely the same manner as in forming the alto. This plate is an exact duplicate of the original, and is called a basso, or an electrotype copy. It requires only a little smoothing on the back, and a removal of any accidental specks or imperfections, to be ready for the printer.

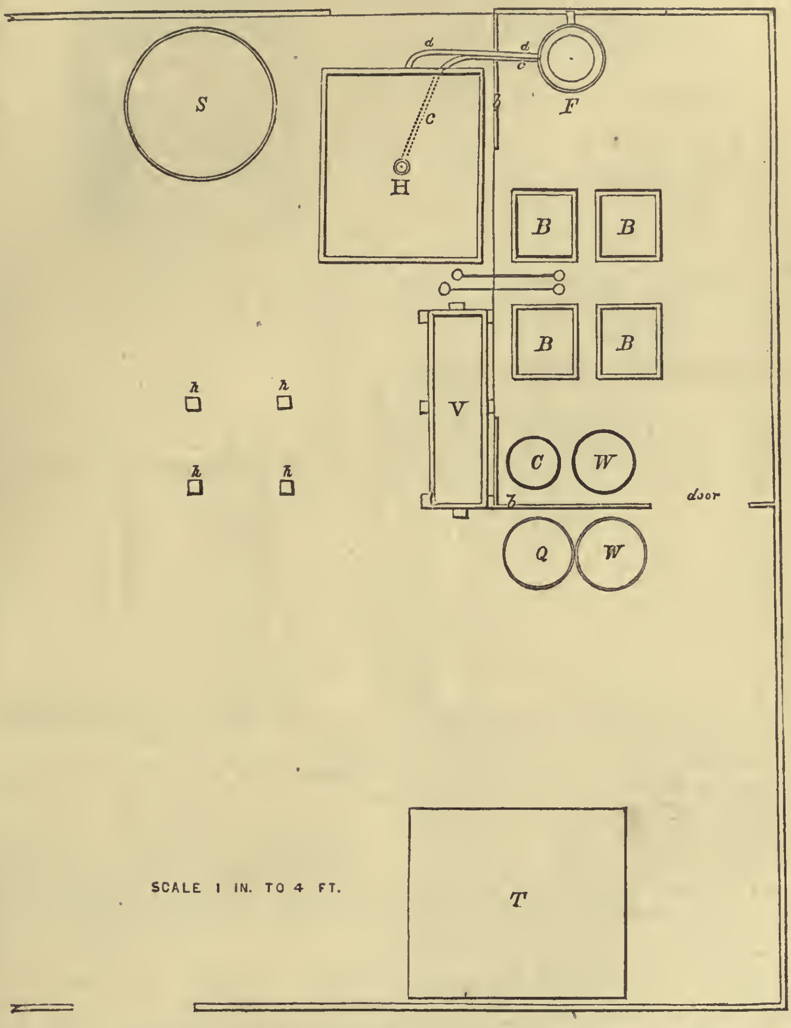
The time occupied in the reproduction of a plate, containing ten square feet, can be brought within a week for forming both alto and basso, though economy of working usually makes it preferable to take somewhat more than this minimum time. A careful regulation of the current under Smee's laws is of great importance, as an indispensable means of securing the requisite metallic properties in the deposite.

Planished copper plates are quite inferior to good electrotypes for printing, as the pure metallic cop-

per resulting from electro-deposition, is free from that porosity which produces cloudiness of impression. The work of inking and wiping an electrotype, is considerably less than for a planished plate, and the wear for each impression is consequently less. We quote from Mr. Mathiot's report, (Am. Journal of Science, Vol. XV., 2d. series, 1853, and Coast Survey Report for 1851, appendix 55,) the following description of the C. S. laboratory, apparatus and manipulations.

"Laboratory Apparatus. Figure 1287 is a plan of the Coast Survey Electrotype Laboratory, the glazed

1287.



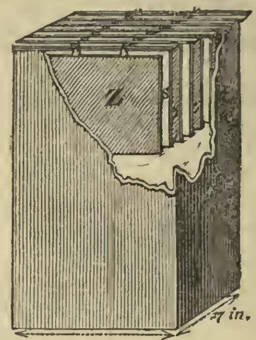
partition, *b*, *b*, *b*, *b*, with a door *d*, separates the battery room from the general laboratory, and permits an easy inspection of the batteries without exposure to their fumes. The laboratory floor is about six feet above the ground, and slopes inward from the sides toward the scuttle holes *h*, *h*, *h*, *h*, arranged for discharging the waste liquids spilled upon the floor. To obviate the deleterious effects of working on a floor saturated with chemical agents, when any solutions are spilled, the floor is well flooded and brushed, the water passing off through the scuttle holes. There are four battery cells, placed as indicated by *B*, *B*, *B*, *B*. A rectangular India rubber bag, supported by a deep wooden box, contains the battery solutions: each cell can contain nine silver and eight zinc plates. A metallic connection unites all the zinc plates of a cell, and another one all the silver plates; each cell can be used as an independent battery, or two, three, or four cells can be connected in consecutive or simultaneous order, or all combined into two pairs of two, in consecutive or simultaneous order, or into the group of three and one of one.

"The position of the vertical decomposing vat is shown at *V*, and that of the horizontal vat at *H*. *S* is a large tub for washing plates. The tub *C* contains the solution of chloride of iron; *Q* is the quicksilver tub, and *W W* are fresh water tubs. *F* is the furnace, and *d d*, *c c*, are heating tubes connecting with the vat *H*. *T* is a flat iron table.

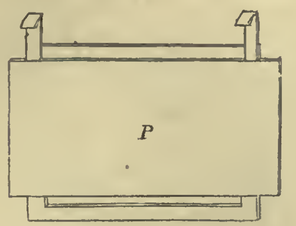
"Fig. 1288 exhibits a cell and its included plates, with their mode of suspension.

"Fig. 1289 represents the suspending frame of wood, and the attached plate P, prepared for immersion in the vertical vat.

1288.

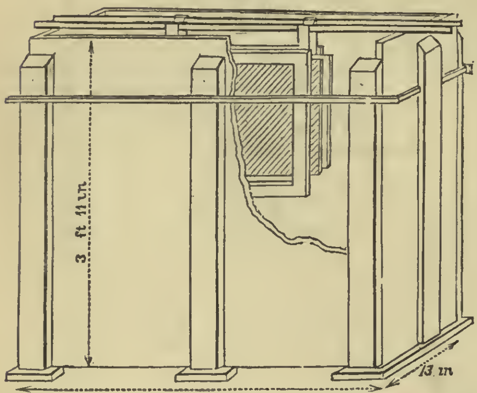


1289.

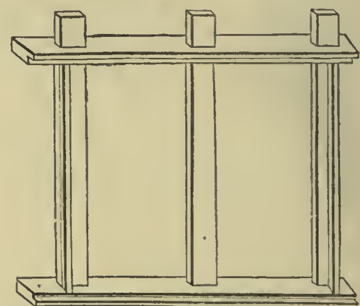


"Fig. 1290 shows the vertical vat and the plates suspended in it.
"Fig. 1291 represents the adjustable plate-supporting frame used in the horizontal vat.

1290.

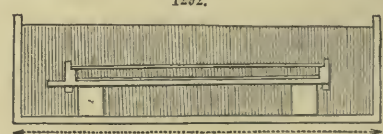


1291.



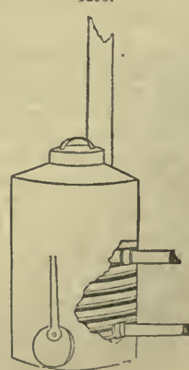
"Fig. 1293 exhibits the interior arrangement of the horizontal vat, a blank plate and an engraved original being in position; also the connecting copper rods leading to the battery.

1292.



"Fig. 1293 represents the heating furnace. The doors for admitting air is shown at a, and is connected with an adjusted compound bar of iron and zinc, that by an adjusted screw it can be arranged to regulate the draught, opening or closing the door, thus maintaining an uniform heat in the solution. After getting the fire started, this door is set so as to close when the solution reaches a heat of 180°. In principle this furnace is similar to a bath heater. A tubular helix of lead is coiled within it, like the worm of a still, and the terminating branches c and d lead to the horizontal vat, the branch c uniting the top of the vat just below the liquid surface with the top of the coil, and d at the bottom of the vat with the bottom of the coil. Hence follows a circulation of the solution from the furnace at top and into it at bottom.

1293.



"Manipulation. When a plate is to be electrotyped, it is placed on trussles above the open scuttle holes h, h, h, h, and thoroughly cleaned by washing with alkalis and acids. It is then silvered, iodized and placed before a window. A plate of rolled copper an inch larger than the engraved plate is then selected, placed on the flat iron table, and beaten with mallets until a steel straight edge shows it to be plane; it is then weighed, and fixed in the vertical plate frame by two copper hooks; the engraved plate is then similarly fixed in a similar frame, when both are placed in a vertical vat and connected with the battery.

"The process does not go on well when the plates are vertical, but it is necessary to start the castings in this position to prevent dust, motes, or specks of impurities from settling on the face. As the rolled plate dissolves, its impurities rapidly render the solution muddy, and endangers the face of the

forming plate. For common electrotypes, dust or mote specks are not detrimental; but the Coast Survey copper plates being not inferior in fineness of lines to fine steel plates, the effect of impurities settling on the face of their copies is to give the impressions a clouded appearance. On first immersing the plate, the solution should therefore be perfectly clean; formerly after each use of the vertical vat, it was emptied and washed out. When the solution had deposited its sediment, it was drawn off and strained through very fine cotton: this whole operation was extremely disagreeable, and consumed a whole day of one man. "By a simple expedient I have saved the necessity of cleaning the vat more than once a month. To guard the new plate from specks and impurities a bag of fine cotton is drawn over a slight wooden frame, which keeps it distended; an hour or more before the solution is wanted, the bag with its included frame, is placed on the top of the solution and loaded with the copper bars used to support the plate-frames. The weight causes the bag to sink gradually, filtering the contained solution as it goes down. The impurities cannot wholly choke the meshes of the cloth, as a fresh portion is constantly brought into action during the sinking. I thus filter the solution without taking it from the vat or disturbing the sediment, saving much labor, time and annoyance.

"The plate remains in the vertical vat over night, and preparations are made in the morning to transfer it to the horizontal vat. The furnace is first brought into action, a new plate of blank copper an inch larger than the matrix, is flattened on the iron table, and bolted to the edges of wooden bars by platinum bolts, for the purpose of preventing the plate from sagging downwards when supported horizontally: the plate so arranged, is called the strapped plate. The coated matrix is then taken from the vertical vat, disengaged from its frame, and arranged in the horizontal frame. A wooden wall an inch high, then surrounds the plate, and on this wall the strapped plate is laid, when the whole combination is placed in the horizontal vat, and the connection with the battery established. The positive plate is then taken from the vertical vat, and its loss of weight noted and recorded. From the known superficial area of the matrix, the quantity of copper required for a casting one-eighth of an inch thick is known and recorded. The blank copper consumed in both vats must equal this amount before the required thickness is reached, allowance being made for impurities of rolled copper and roughness on the back of the electrotype.

"After a few hours of action, the strapped plate becomes so loaded with impurities that they will begin to drop on the electrotype; this plate must, therefore, be removed from the vat, and a new one immediately supplied. The dirty plate is then washed in the large water tub, and when cleaned its loss of weight is found and recorded. By the amount of loss the action of the batteries is tested, and it is found, if Smee's laws are being observed. Vigilance must now be exercised in watching the batteries and vats of work, and the power must be varied to suit circumstances. The entire working battery generally requires renewal once a day, the process being conducted as follows:—One zinc and one silver plate are taken from the battery; the silver placed in the solution of the chloride of iron, and the zinc taken to the water tub outside the door of the battery room, where it is scrubbed clean with a hard brush; it is then re-amalgamated at the quicksilver tub and taken back to the battery. The silver plate is transferred from the chloride of iron solution to the adjacent fresh water tub: another plate is then transferred from the battery to the chloride solution, and another zinc cleaned, washed, and put back in the battery with the first silver. In this manner the whole battery can be renewed without sensibly interrupting its action.

"When the loss of weight from the rolled copper in both vats indicates that the required thickness of the electrotype is gained, the plate is withdrawn from the battery, detached from its frame, its back smoothed, and its edges filed until a separation can be made. By separation the original becomes liberated, and the alto or reversed relief, is silvered and electrotyped exactly as an original. The copy from it, or the electrotyped basso, will, if the process has been properly conducted, be a perfect fac-simile of the original, and in hardness, ductibility, and elasticity, will equal the best rolled and hammered, or planished copper plate."

In no application of electro-metallurgy is the value of the science more conspicuously shown than in a mode of producing surfaces for printing lately patented and called *Glyphography.*

All our previous operations have been conducted at the negative pole of the battery; but at the positive pole certain effects take place which may be taken advantage of in the arts. Let us call to mind the fact, that gold, silver, and all metals with a greater affinity for oxygen, are dissolved when made the positive pole of a cell charged with a solution of the same metal. This property may be easily shown by attaching wire by one of its ends to the silver of the battery, and placing the other in a solution of sulphate of copper, in the bottom of which a piece of copper connected with the zinc of the battery is immersed. After a short time, the wire will begin visibly to be dissolved, and the part nearest the negative metal will be affected; the copper in every place is dissolved exactly in proportion to the electricity passing.

In order to make an etching, a copper-plate is first to be prepared by covering it with a substance which protects it from the action of the acid in which it has to be immersed: this substance used is composed of asphalte and wax in equal proportions, combined with a fourth part of both black pitch and burgundy pitch. This mixture is placed in a piece of silk, and rubbed over the copper-plate, which is kept at a moderate heat, by holding it over a lamp or chafing-dish. This operation is technically called laying a ground; this at first is colorless, but it is afterwards blackened by holding it over the flame of a candle, and depressing it till a copious supply of smoke covers the surface.

The engraver, with an instrument like a needle, called an etching-point, executes his drawing, and in so doing removes the ground, and exposes a clean surface of metallic copper. The plate is then placed in a dish, and dilute nitric acid poured upon it, till the copper is dissolved out from the exposed lines to a sufficient depth. The plate is not allowed to remain in the acid a sufficient length of time to bite deeply, as this would cause the engraving to be of one degree of blackness; but after it has been in the acid a short time, those parts which are required to be of a light shade are stopped out, that is, they

are covered with brunswick-black, or a coat of varnish capable of resisting the action of the acid. The plate is then replaced in the dilute acid: after a time it is again removed, and a further portion is stopped out; and these operations are repeated as many times as there are differences of shade required in the engraving. The degree of perfection that the professed engraver obtains by practice is truly extraordinary, considering the uncertainty which must attend the operation; for the action of nitric acid is not subject to any regular laws, and moreover is never alike over all parts of the same plate. This is owing to the copper-plate itself being never pure; but always containing tin, dispersed here and there throughout its texture, which resists the action of the acid. After a splendid plate is bitten in, some portions are sometimes left which cannot be acted upon by the nitric acid, but absolutely require the graver to bring up the fine lines.

No engraver that I have conversed with, can explain the cause of these faults in their work, but to the chemist they are perfectly intelligible: the nitric acid attacks the copper, forming a soluble nitrate of that metal which is dissolved in the fluid; but the action of nitric acid on tin is altogether different, for it converts the metal into a peroxide, which, being insoluble, protects the copper from the acid. The engravers have always noticed this white powder, (the peroxide of tin,) so fatal to the success of their operations.

Etching by galvanism is a far more certain operation than the foregoing, because it can be reduced to known principles. In this case, the plate to be bitten in has the device first drawn upon the same ground that is used in the ordinary process; the back and edges of the plate are then coated with wax, and it is to be connected by means of a wire with the silver plate of one or two of my batteries.

The piece of copper to form the negative pole should then be connected to the zinc, when both the copper-plate and the piece of copper are to be placed in a solution of sulphate of copper. Immediately copper will be reduced from the solution on the negative plate, and copper from the etching-plate will be dissolved to keep up the strength of the solution.

Whatever is favorable to the increase of electricity, causes the copper to be more quickly acted upon, and whatever diminishes the galvanic current, retards the solution of the metal; the nearer the etching plate forming the positive pole, and the piece of copper forming the negative are approximated, the more rapid will be the action. In the same way, the intensity of the battery also affects the rate at which the plate is bitten in. The negative plate of copper, however, should not exceed in size the copper-plate on which the etching is executed, or else there is a risk of some of the lines being more deeply bitten in; and in like manner, if any considerable part of the plate has a great deficiency of lines compared with other parts, that part must be stopped out rather before the other, to ensure a uniformity of depth, or else the negative copper opposite this part must be bent in such a way as to increase the distance.

The advantages of galvanism for etching, are, the absence of poisonous nitrous fumes, which are evolved in the ordinary process; the greater uniformity of action which takes place than when acids are used; and the rapidity of biting, which may be regulated to the greatest nicety. The lines may be made of any depth, and are sharper and cleaner than when acid is used; and lastly, no bubbles are evolved, which the engraver well knows are apt to tear up the ground, or to cause unequal action.

The exact quantity of copper dissolved from the plate, can be ascertained by weighing the metal reduced on the sheet of copper which forms the negative pole, or by measuring the quantity of hydrogen evolved from the silver plate of one of the platinized silver batteries; for thirty-two grains of copper will be dissolved for every forty-eight cubic inches of gas evolved.

Etching by galvanism can be executed with any desired degree of rapidity, according to the series of batteries to which the plate is connected; but I believe that the practical man will find that the action should neither be too slow nor too quick, and perhaps two or three batteries, arranged as a series, will be found best adapted, though a single cell would suffice.

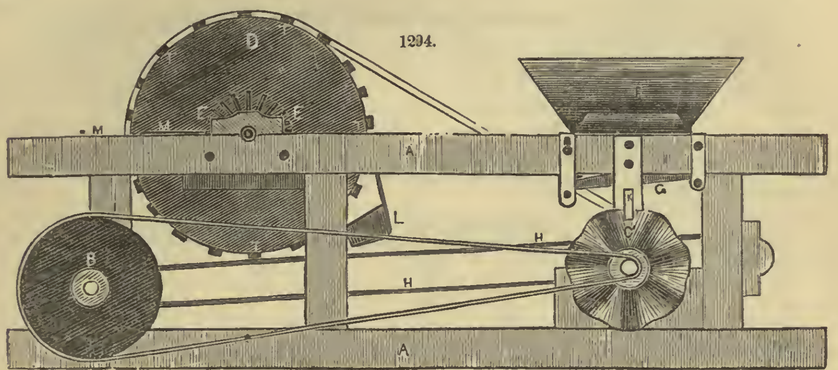
Galvanism would be valuable to the engraver for executing gradations of shade, such as, for instance, the effect of a strong light illuminating a whole room. The most simple manner in which this can be shown, is to take a copper-plate and draw a number of lines on the ground with a ruling-machine The plate, after having its back and edges coated with any non-conducting substance, should be then connected with the silver of the battery, and copper wire. These two should be then arranged in the solution of sulphate of copper, that at one end they nearly touch, while at the other they are widely apart. By this position, the greatest quantity of electricity would pass at that part of the plate where it is nearly in contact with the negative pole, whilst the least would pass at the opposite extremity. The action on the etched plate being exactly in proportion to the quantity of electricity passing, is unequal over the whole length of the plate, being greater where the metals are nearest, and gradually diminishing to the other end. This is the most perfect mode by which it is possible to obtain a gradation of shade. Many variations in the arrangements might be made by using, as a negative plate, a wire or a rod of copper, placed over the centre of a prepared plate; for then a perfect gradation would be obtained, extending in all directions from the dark centre. In the same way, two or more radiating shades may be obtained, by using two or more negative wires. An insensible gradation might be made from the darkest shade at the external edge of the plate, to the lightest point at its centre, by cutting out a hole in the negative piece of copper, opposite to the part where the transition into light is required.

The professed engraver who once practically masters the galvanic method of etching by the theoretical principles which I have here detailed, is sure to obtain great results. He could execute with ease the most extraordinary transition of light into darkness with fidelity, and with the utmost certainty

Galvanic etching has lately extended to the etching of Daguerreotype plates. The silver plate is arranged as the positive pole in a trough, by connecting it to the negative plate of a battery. The silver plate is about the same size as the Daguerreotype; but I believe that we should be able to bite much deeper by following the improvements in galvanic etching. It is stated that these etchings when printed showed extraordinary minuteness of detail.

ELECTRO-MAGNETIC ORE-SEPARATOR, Cooks. Fig. 1294 is a side elevation of the machine A A is the frame. B is a pulley by which the cam-shaft C is revolved. This shaft, by the cam C, shakes the hopper F so as to spread the ore evenly across the endless web or carrying-apron H. This is done by having a hook-rod K that catches the upper edge of C, and is made, from the shape of the cam, to traverse across the web, and spread the ore equally on the web. D is the revolving magnet cylinder, driven by band and pulleys O N P. L is the trough into which the ore is discharged from the cylinder. X X are mercury troughs, the one charged positively and the other negatively from the battery, by the wires M M. The magnets are fixed on the revolving cylinder, and wound round with copper wire, the one positive and the other negative. These wires are carried from one magnet to another across the row, and brought out at the axle of the cylinder, forming a circular fan E, so that as the cylinder revolves, and the wires dip into and rise from the charged mercury troughs, the rows of magnets are charged and broken alternately, to lift the ore from the dross and deposite it in the receiving troughs.

1294.



The magnetic cylinder revolves to meet the ore as it comes forward on the web, and in the same direction. T T are the magnets. M represents the wires from the battery. The large cylinder is revolved by a band from the other side, passing over a pulley on the shaft of D, the magnetic cylinder. The cylinder is made of wood, a non-conductor; and to insulate the wires perfectly, the axle of the cylinder is boxed with wood, and wires turned up on the outside of it.

1295.

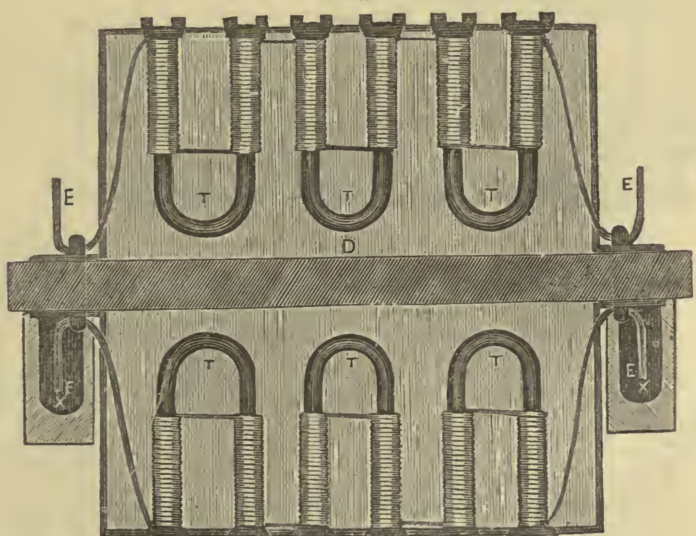
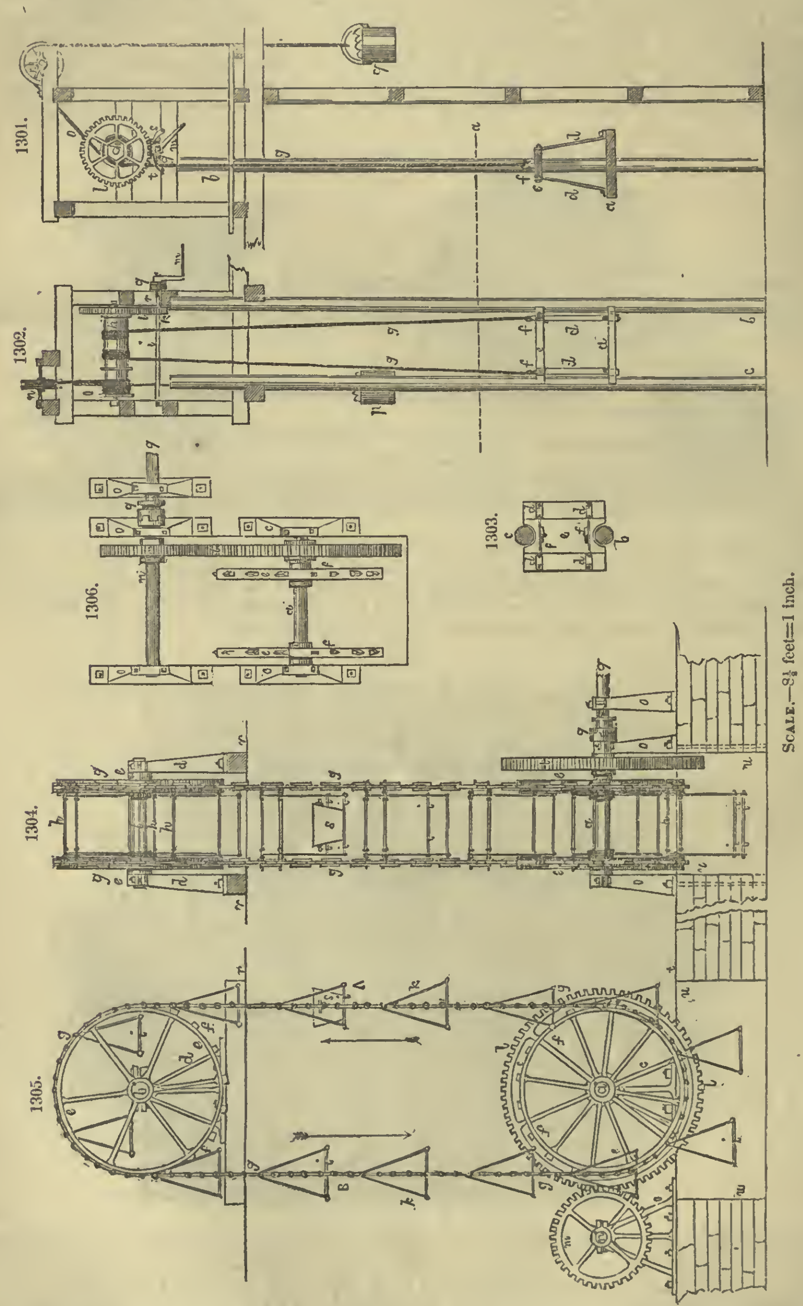


Fig. 1295 shows the manner in which the magnets are arranged on the cylinder. D is the cylinder; T T the magnets; E the current wires; and X the trough of quicksilver. The cylinder is about 30 inches in diameter, and the magnets are about ⅝ of an inch thick, with four polar points. There is a space of about ¾ of an inch between each of the magnets, and a large cylinder has had thirty rows of ten magnets each. It will be observed that the wires are alternately wound in the direction of the polar currents. One wire is now represented as dipping in the mercury; but one-fourth of all the magnets are charged at the same time, as that number touch the mercury on the under side of the

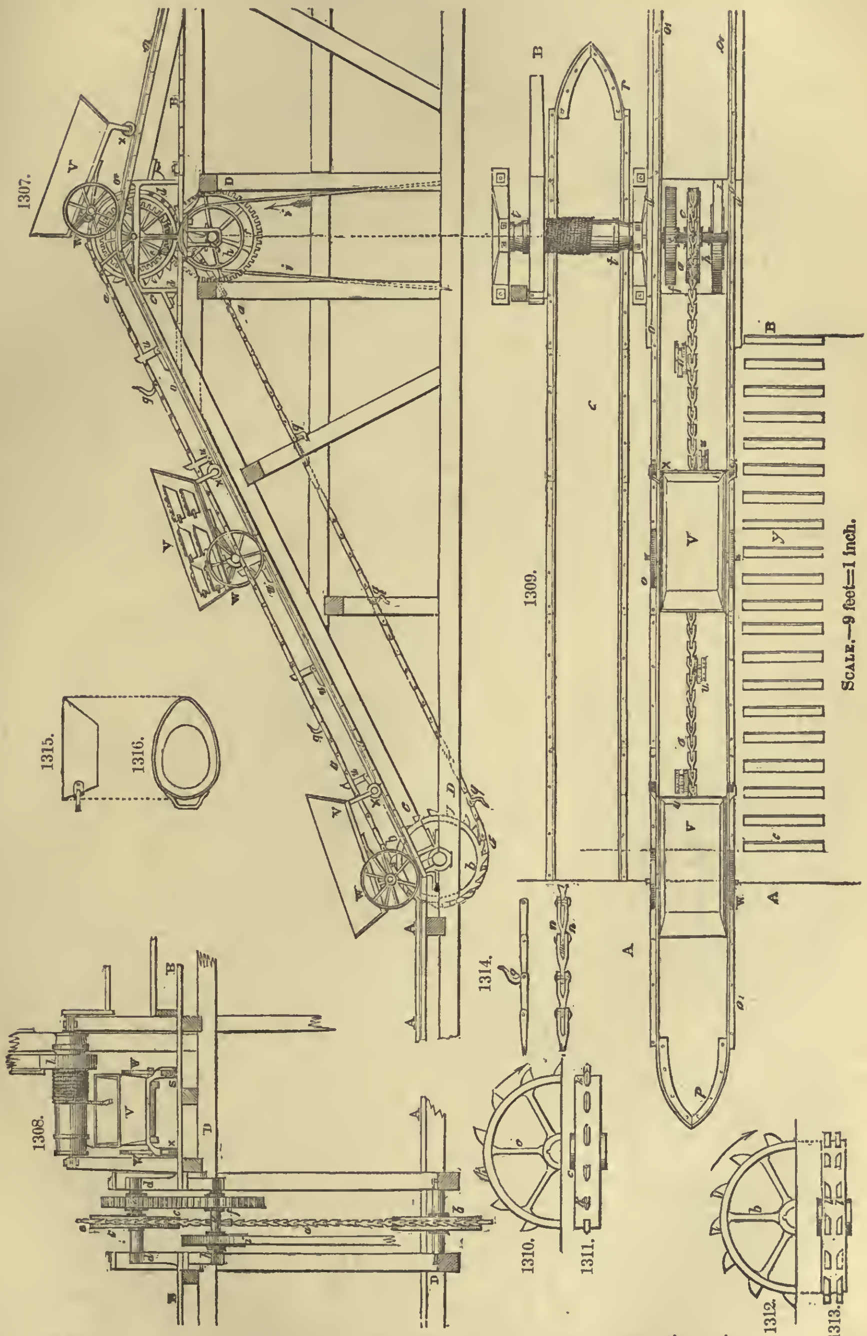
cylinder; but the magnets are charged and discharged successively in rows. The ore is carried forward on the endless apron; and the magnet cylinder, by revolving in the same direction as the apron, lifts the ore, while the dross is discharged from the apron while passing over the roller.

This machine has been in operation at Plattsburgh for some time, where it is stated to have exceeded the most sanguine expectations. When ore is associated with hornblende no other process of separation can, it appears, compare with this.



ELEVATORS. The general term Elevator includes gins, windlasses, cranes, &c.; but since these are described under their separate heads, in this article are comprehended only those smaller machines employed to raise materials in mines, furnaces, factories, and corn-mills.

Figs. 1301 to 1303, a vertical elevator, moved by hand.
Figs. 1304 to 1306, a similar one, driven by steam or water-power.
Figs. 1307 to 1316, a single elevator working on an incline with an endless chain.
Figs. 1317 to 1321, a similar one, with a rope.
Figs. 1322 to 1325, a similar one, but double.



Figs. 1326 to 1328, an elevator moved by condensed air or a pneumatic engine.
Figs. 1329 to 1333, elevators for corn-mills.
Figs. 1334 to 1337, elevators for factories.
Figs. 1338 and 1339, elevators for general purposes.

A vertical Elevator, moved by hand.—Fig. 1301 is a side elevation; Fig. 1302, a front elevation; Fig 1303 a section on the line *a b*. The weight to be raised is placed on the platform *a* of the frame *a d e*, which, moving between the posts *c b*, is retained in position by grooves in *a* and *e*, as shown clearly in the section, Fig. 1303. The platform is raised by the winding of the chains or ropes attached to the frame at *f*, on the barrel *h*, which, if the weight is trifling, is turned by a winch on its own shaft, but more commonly an extra shaft *i*, geer *l*, and pinion *k*, are employed with the winch *m;* two ratchet-wheels *q r* and catches *s* and *t* hold the platform in any desired position. A counterpoise *p* is attached by the rope *o*, passing over the pulley *n* to the barrel *h*.

A vertical Elevator, driven by steam or water power, used in the iron-works of Belgium.—Fig. 1304 is a front elevation; Fig. 1305, a side elevation; Fig. 1306, a plan of the lower part. The parts are as follows: The standards *c* and *d* support a lower shaft *a* and upper *b*, to each end of which are fixed the iron wheels *e e*, of about 7½ feet diameter and 7 inches wide, cast with projections *f f*, adapted to the links of the endless chains *g g;* at distances of about 5 feet the two chains are connected by iron rods *h h h*, from which depend the platforms *i k*, on which are placed the loads to be raised or lowered. These weights can be put on or taken off while the machine is in motion, and if from neglect the load is not removed, the only result is that it continues to ascend and descend with the revolutions of the wheels *e e*. Motion is communicated through the shaft *p*, the pinion *m*, and the geer *z*, fixed to the shaft *a: q* is a slide coupling; *o o*, standards of the shafts *p* and *n:* and *u* a pit or span necessary below *a*, for the passage of the platforms.

An Elevator working on an incline, with an endless chain, used at some of the blast-furnaces of Belgium.—Fig. 1307 is the side elevation; Fig. 1308, the rear elevation; Fig. 1309, the plan. A A is the bottom, and B B the top platform; C C the railway, inclined at an angle of about 30°, and supported by the frame D D. The wagons are drawn up by the endless chain *a a a*, resting loosely in the wheels *b b c c*, to which last motion is communicated through the geers *e* and *f*, and the pulley *h*, over which passes a band *i* from the prime mover. Figs. 1310 and 1311, represent two views of a portion of the wheel *c c;* Figs. 1312 and 1313, of the wheel *b b;* Fig. 1314, of the chain. It will be seen that there is but one row of projections *k k* on the rim of the wheel *c*, fitting the openings *m* of the links of the chain, while on *b* the row is double, and is adapted to the spaces *n n* of the chain.

The loaded wagon being brought to the bottom of the incline, the hind axle is caught by one of the hooks *g*, (which are about 9 feet apart,) and is drawn up. At the top the wagon is received on a small descending railway, inclined at an angle of about 5°, and whose summit is sufficiently above the platform B B, that gravity alone will carry the wagon to its place of unloading. The emptied wagons are placed on a side track *s s*, and are lowered by means of a rope attached to the windlass *t t*, Figs. 1308 and 1309.

Along the railway *o o*, and at a distance of from 5 to 6 feet, are placed the moveable catches or bell-levers *u u*, which, in case of the breakage of the chain, will catch the hind axle and stop the descent of the wagon.

The wagons used in Belgium are composed of cast and wrought iron, and the materials for supplying the furnace are first put in plate-iron vessels, (holding from 30 to 40 pounds, and of the form represented in Figs. 1315 and 1316,) and then placed in the wagons, which contain from 12 to 18 of them.

An Elevator working on an incline with a pulley-rope.—In blast-furnaces, where only charcoal is used, the elevator, represented in Figs. 1317 to 1321, is frequently employed. Fig. 1317 is a side view; Fig 1318, a plan; Fig. 1319, a section on the line A B; and Figs. 1320 and 1321 are details.

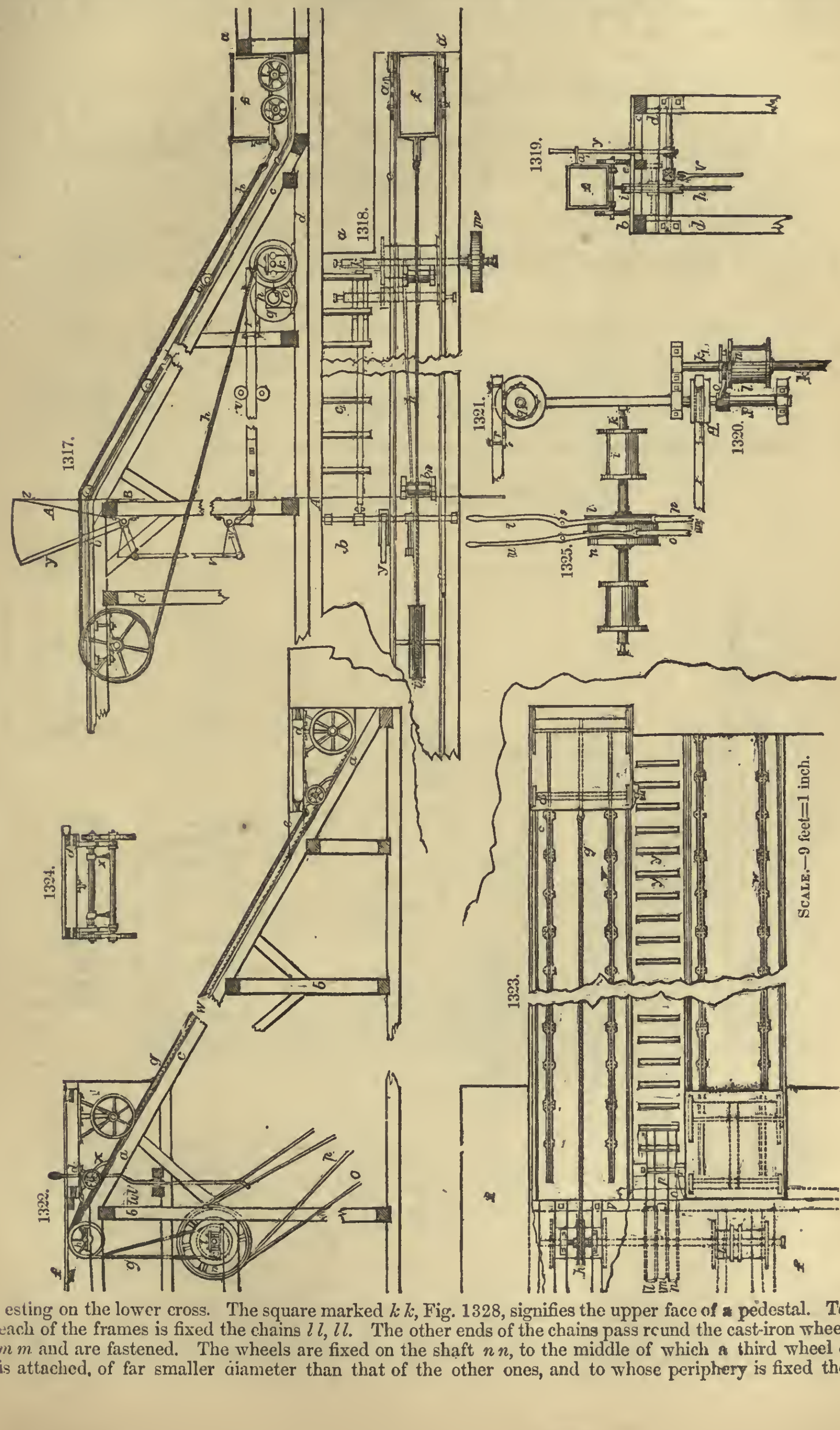
The principal axis $k\,k_1$, Fig. 1320, is at *k*, where the drum *l* is cylindrical, and at k_1 squared. On this part is placed the moveable wheel *m*, with the knobs *n n*, which are inserted into corresponding holes of the drum *l*, whenever this latter is to follow the movement of the axis $k\,k_1$. In the periphery of the wheel is carved a groove, into which fits the quadrant *o*, Figs. 1317 and 1320, wound like the worm of a screw, and fixed to the shaft *p*. To this shaft is also fixed the disk *q*, Figs. 1317, 1320, and 1321, on whose periphery is placed the bar *r r*, which is joined to it by the counter-chains *s* and *t*, Fig. 1321, in such manner that the wheel, together with the shaft *p* and quadrant *o*, is alternately turned to the left and to the right, according as the bar is pushed backwards or forwards. By this the wheel *m* is either moved on or off the drum *l*, and consequently the latter is brought in or out of connection with the axis $k\,k_1$.

A double Elevator working on an incline with pulley-ropes.—At blast-furnaces, where the smelting of the ore is effected by means of coke, and large quantities of iron, stone, fuel, and other supplies are to be conveyed up to heights of 30 or 50 feet, several of these elevators are applied. On the inclined plane, forming an angle of 30 or 40°, are two railways, parallel to each other; the one serving for the ascent of the charged wagon, and the other for the descent of the empty one. An elevator of this kind is represented in Figs. 1322, 1323, 1324, and 1325. Fig. 1322 is a side elevation; Fig. 1323, a plan; Fig. 1324, a front elevation; and Fig. 1325 represents the principal axis with its two drums and levers for moving out and in the clutches.

An Elevator moved by condensed air or pneumatic engine.—At the iron-works of Chatlinot, near Charleroi, in Belgium, an elevator of this description, and about 50 feet in height, was constructed in 1839, for three blast-furnaces, where the smelting of the ore is effected by means of coke. The condensed air, required as motive power, was derived from the great wind-reservoir of the blast apparatus, the air here being condensed at the rate of 4 pounds pressure on the square inch. This elevator is represented on page 460, where Fig. 1326 is a side elevation; Fig. 1327, a front elevation; and Fig. 1328, a horizontal section of a part immediately above the cylinder.

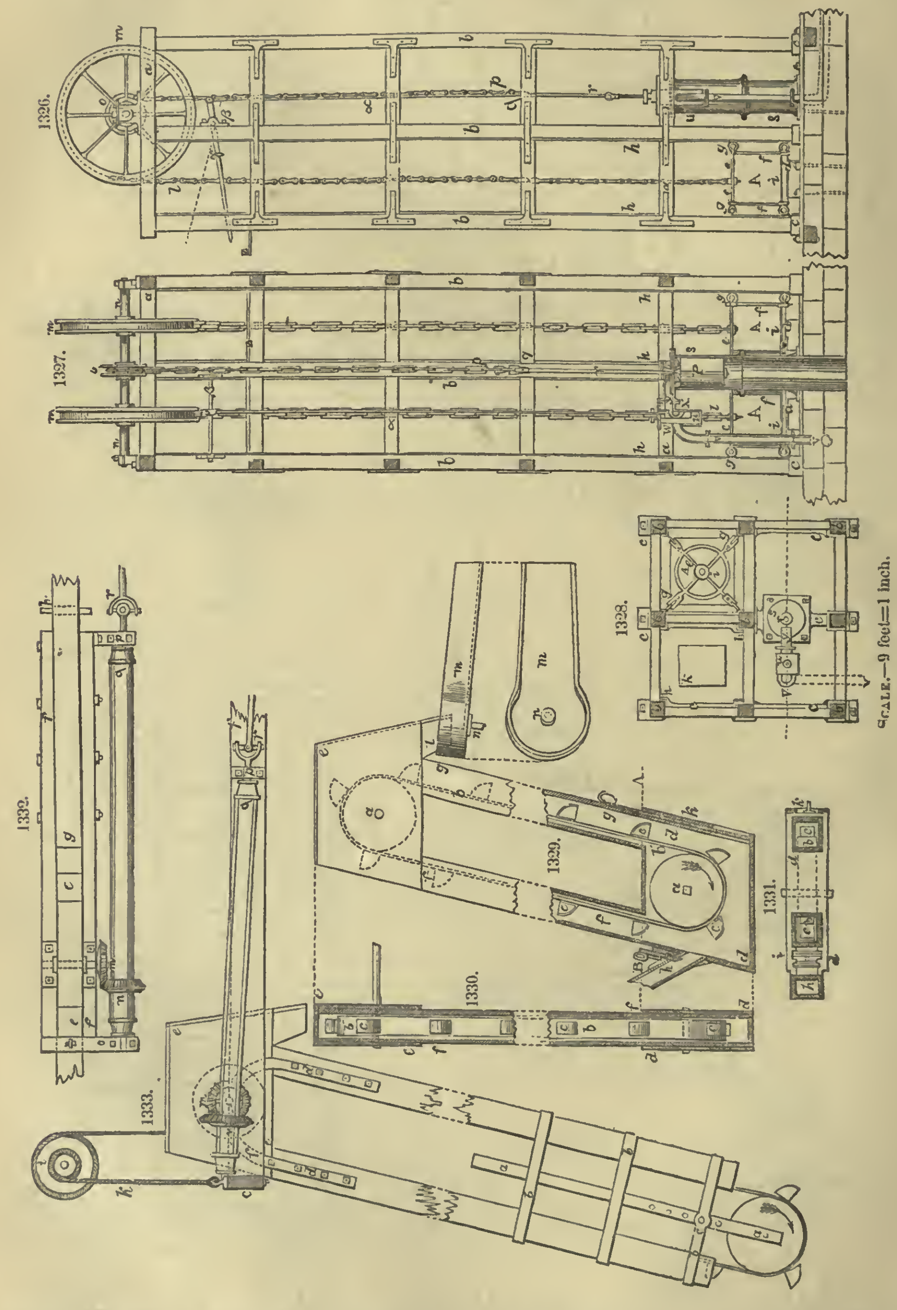
The frame *a a*, Figs. 1326 and 1327, is composed of upright standards and cross-bars, whose joints are, for the sake of durability, covered with iron bands. The nine vertical beams *b b b* form in the plan four equal squares, Fig. 1328. They rest on cast-iron pedestals *c c*, Fig. 1326 and 1327, and into whose holes they are firmly fixed by means of wooden wedges. In two of the squares, by the side of each other, the iron ore and other materials are drawn up in vessels or tubs A A, one of which is represented in Fig. 1328 The vessels are provided with two cast-iron crosses *d d* and *e e*, joined by the wrought-iron bars

f f. The cross-arms form diagonals of the squares, and are at their ends provided with rollers *g g g g*, grooved at their periphery, to fit the rectangular rails *h h h h*, on which they run up and down from the bottom to the top of the elevator. The vessels containing the ore, etc., are placed on the iron plate *i i*



esting on the lower cross. The square marked *k k*, Fig. 1328, signifies the upper face of a pedestal. To each of the frames is fixed the chains *l l*, *l l*. The other ends of the chains pass round the cast-iron wheel *m m* and are fastened. The wheels are fixed on the shaft *n n*, to the middle of which a third wheel *o* is attached, of far smaller diameter than that of the other ones, and to whose periphery is fixed the

chain $p\,p$, fastened at its lower end to the joint-head q of the piston-rod r. The piston P moves up and down in the air-cylinder $s\,s$, which is about 10 feet high, 2 feet in the diameter, and open below. The piston-rod is packed as in a steam-engine. At the side of the cylinder is the valve-box u, Fig. 1327 which receives the condensed air from the reservoir of the blast apparatus through the pipe $v\,v$, and from which again it can be let into the cylinder $s\,s$, by means of the valve w, Fig. 1327. The valve



is hollow, to permit the escape of the condensed air (after it has pressed down the piston to the extremity of the cylinder) through the aperture x. As soon as the valve w is moved out of its position, as shown in Fig. 1327, downwards, (which is effected by the combined contrivance of the bar α, the shaft β, and the lever γ,) the condensed air acts on the piston t and presses it down. The effect of this

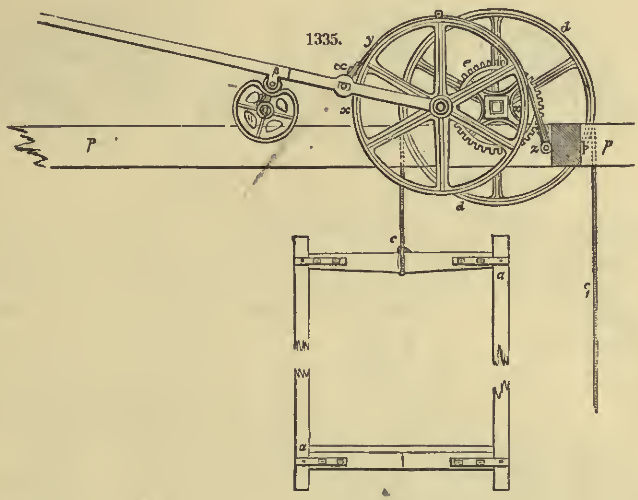
is, that the vessels A A are drawn up simultaneously with a velocity surpassing the movement of the piston in proportion to the difference in diameter between the wheels *m m* and the wheel *o*.

As soon as the vessels are lowered again, the slide *w* is drawn upward; and as the condensed air filling the cylinder, escapes through the aperture *x*, the vessels A A sink down by their own weight, which surpasses that of the counterbalance P. The piston *t* is at the same time drawn up to the upper part of the cylinder.

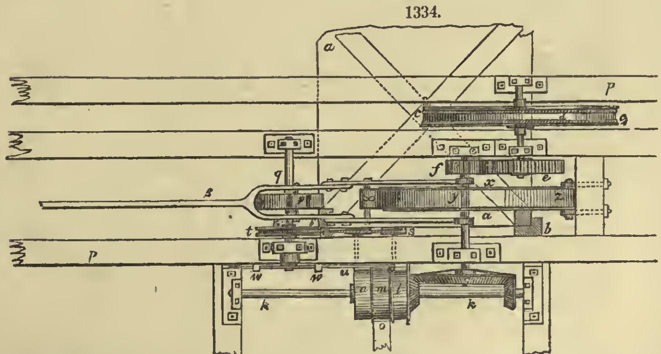
Elevators in corn-mills, etc.—Elevators of this kind are very frequently used in corn-mills and granaries for the purpose of raising corn or flour from one loft to another. Elevators for corn are in general of larger size than those used for raising flour, although both are constructed and arranged on the same system.

An elevator of this kind is represented on page 460, where Fig. 1329 is a side elevation, Fig. 1330 a front elevation, and Fig. 1331 a section of its lower part, (from the line A B, in Fig. 1329, downwards.) Around the wheels *a a* is strained the band *b b b b*, to which are fastened or riveted the vessels *c c*, of tinned sheet-iron. Motion is generally communicated to the upper wheel by bands from some driving-shaft. Each of the two wheels is enclosed by a wooden case, the lower one by the case *d d*, and the upper disk by the case *e e*. The interstices or channels *f f* and *g g* are so arranged, that in the former the band with its vessels has but little play, while in the latter more space is given to prevent any collision with the vessels *c c*, which otherwise might happen on account of the inclined position of the elevator.

1335.



1334.



The corn or flour pours into the lower case by the channel *h*, and the influx can be regulated, or, if required, entirely stopped, by the shutter or slide *i*. In the rear of the same case is the shutter *k*, for the clearing of the case and removal of obstructions.

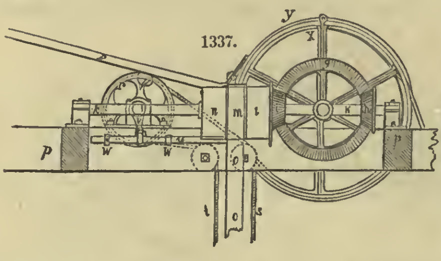
At the bottom of the upper case is the aperture *l*, into which is thrown the grain or flour from the vessels *c c*, as they overturn on the upper wheel. From *l* the corn or flour is distributed by the trough *m*, turning on the bolt *n*, or is in some other way removed to its place of destination. See Corn Elevator.

Elevators in factories for removing manufactured and other goods from one room to another.—An elevator of this kind is represented above, where Fig. 1334 is a plan, Fig. 1335 a side elevation of a section towards the middle, Fig. 1336 a transverse section, and Fig. 1337 a side elevation, showing the mechanism of the prime movers.

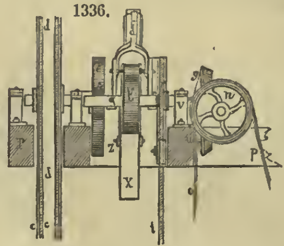
In a square space passing through all the stories of the factory, the frame *a a*, Figs. 1334 and 1335, moves up and down, of about 5 feet square between two beams *b b* placed alongside of each other. It

is driven by the same power that drives the factory. The frame is fastened to two ropes or bands c and c_1, passing over the cast-iron wheel *d d*. To the other end of the rope c_1 is fastened a counterpoise of the frame, or of the charge to be raised. On the shaft of the wheel *d d* is fastened the spur-wheel *e e*, into which the spring-wheel *f* plays, Fig. 1334, on the opposite end of whose shaft is the diagonal wheel *g*. Into this latter geer, simultaneously, the two smaller diagonal wheels *h* and *i* of the axis *k k*, to which the wheel *h* is firmly fixed, while the wheel *i* is moveable on it. On the latter wheel is screwed the cast-iron roller *l*, by the side of which are two other ones of the same size, *m* and *n*, the former being moveable and the latter fixed on the common shaft *k k*. The band *o o*, Fig. 1336, connected with the motive power, passes round one of these three wheels. Suppose it be the wheel *n*, the shaft *k k*, together with the wheel *h*, is revolving in the same direction as the band moves round. Consequently the shaft of the wheels *g* and *f*, and at the same time the wheel *d d* rotating by the action of the wheel *h*, the frame *a a* is raised, while the wheel *i* is by the wheel *g* turned round, and rotates freely on the axis *k k*, in a direction the reverse of that of the band. If, on the other hand, the band *o o* is removed from the disk *n* to *l*, by which the wheel *i* takes into the wheel *g*, while the wheel *h* is now kept out of action, the frame *a a* is moving downwards. Finally, if the band be placed round the moveable wheel *m*, the elevator is in the state of rest; this wheel then revolves on the axis *k k*, without exercising any action.

1337.

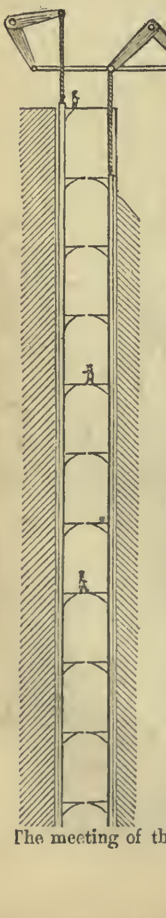


1336.



For the purpose of removing the band from one of the three wheels to another, and to regulate the different movements in the described manner, the following arrangement is made. The beam *p p* supports the bearings of the shaft *q*, (parallel to that worked with *g f*,) on which is fixed the wheel *r*. An endless rope *s t*, Fig. 1337, stretching from the top to the bottom of the building, passes round this wheel, and can every where easily be seized by the workmen. Now, according as the part *s* or the part *t* of the rope is pulled, the disk *r* or the axis *q* are turning either to the right or to the left, and by this and the handle *v*, the sliding bar *u* is pushed either onwards or backwards. This bar being fastened to the band *o o*, by means of a fork or handle, the band is removed to one of the three disks *l*, *m* and *n*. The distances between the two guides *w w* of the sliding-bar *u*, are exactly adjusted to these shiftings of the band *o o*.

1339.



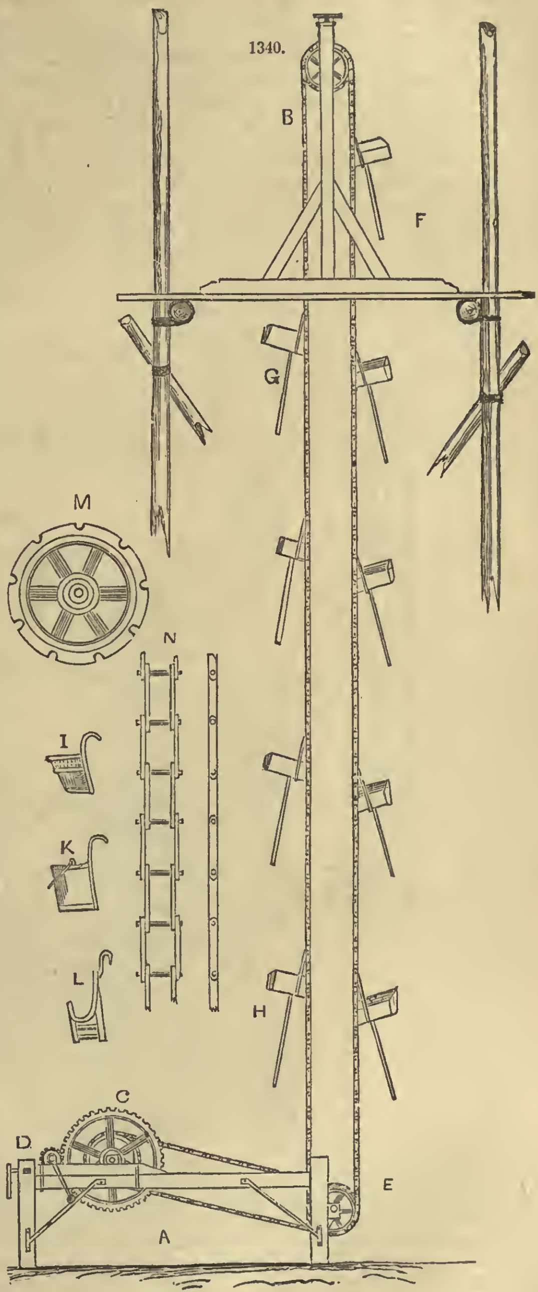
For stopping the movement of the frame *a a* whenever required, a contrivance is made, consisting of the wheel *x*, Figs. 1335 and 1337, on whose periphery is laid the band *y* of strong sheet-iron. This band is fixed at *z*, and with the other end fastened at *a*, to the lever *β*, resting on the heart-shaped wheel *γ* which is fastened on the axis *q*. Now, as soon as the band *o o* is placed round the wheel *l* or *n*, the band *y* is lifted, and together with it the lever *β*. But as soon as the band *o o* is removed to the wheel *m*, the lever lowers again, resting with its roller in the concavity of the disk *γ*, Fig. 1335.

Elevator for Descent and Ascent of the Workmen. In mines this subject is frequently less attended to than it deserves. The common method of descending a shaft is by means of ladders: this is tedious. In other instances, flights of stairs are provided, on which the labor of ascent and descent is less tedious, but is equally difficult. Our mines are not generally deep, but those of 300 and 400 feet in depth require some exertion on the part of the workmen to enter and leave the mine. This operation is frequently performed by the workmen who step on the platform, or in the buckets, and are thus hoisted or sunk by the engine. This is dangerous. For ascent and descent no apparatus is more suitable in our country than that which is contrived in some of the German mines, and is now also employed in some of the English mines. It is represented in fig. 1339: two rods descend the whole length of the shaft, which may be of wood or iron; the first material, however, appears to be preferable. In order to secure the safety of the men, in case any part of the machinery should break, balance pulleys are fastened at certain distances, over which a chain is slung which balances the weight of that part of the rod below the pulley, and in case one side of the machine is injured by breakage, it will be moved by the other side, and no interruption of the regular motion will happen; the men are therefore perfectly safe. These balance pulleys may be in distances of a timber's length, say from 50 to 60 feet. To the rods platforms are fastened, so that one or two men may stand on each: these platforms are from 10 to 20 feet apart, to which the lift of the rod corresponds. The opposite platforms meet at the dead points of the up and down motion, and at this culmination the men step from one platform over to the other, and by this motion from one side to the opposite they may either ascend or descend, as they choose. The meeting of the platforms being at the dead points of the cranks, there is a short rest in the motion

of the rods, and the change of place may be accomplished with perfect safety by the men. The motion of these rods may be accomplished by means of cog-wheels, or by means of cranks or levers.

The rods may in the mean time serve as pump-rods, driving a set of pumps at the bottom of the pit, or a system of pumps at various heights.

ELEVATOR, *for raising bricks, mortar, and any other materials employed in building, and adapted to the unloading of ships and warehousing of goods.* Invented by M. Spurgin. Fig. 1340.



Description of machine.—The main part of the machine A, consisting of the geering to set the machine in motion, rests upon the ground. The second part is a trestle, which may be placed upon the scaffolding of the bricklayers, as at F; in the upper part of this trestle is an indented wheel B, which corresponds perpendicularly with a similar wheel, attached to the principal body of the machine, resting on the ground. Passing round these two wheels is an endless iron chain, which is put in motion by one or several men, who turn the handle of the machine A, consisting of a pinion-wheel working into a large toothed wheel, on the axis of which is an indented wheel, round which an endless chain passes, and also round a corresponding wheel at the side of the one at the foot of the vertical chain; the latter is set in motion when the wheel A revolves, together with the endless chain just described, over the indented wheels at C and E by which the chain operates its rotation. On the side of the chain ascending, the workmen attach their hods full of materials, by means of a hook fixed in the hod, as at B, and others detach them, as at F, to carry them to the bricklayers on the scaffolding. The empty hods are attached to the chain on the opposite side, as at G, and descend to the ground, where they are detached, as at H.

The chain may be lengthened and shortened as necessary. When a story is added to the scaffolding, the trestle is placed upon the new story, and the chain lengthened as required. At the top is a screw for tightening or relaxing the chain, as occasion may require.

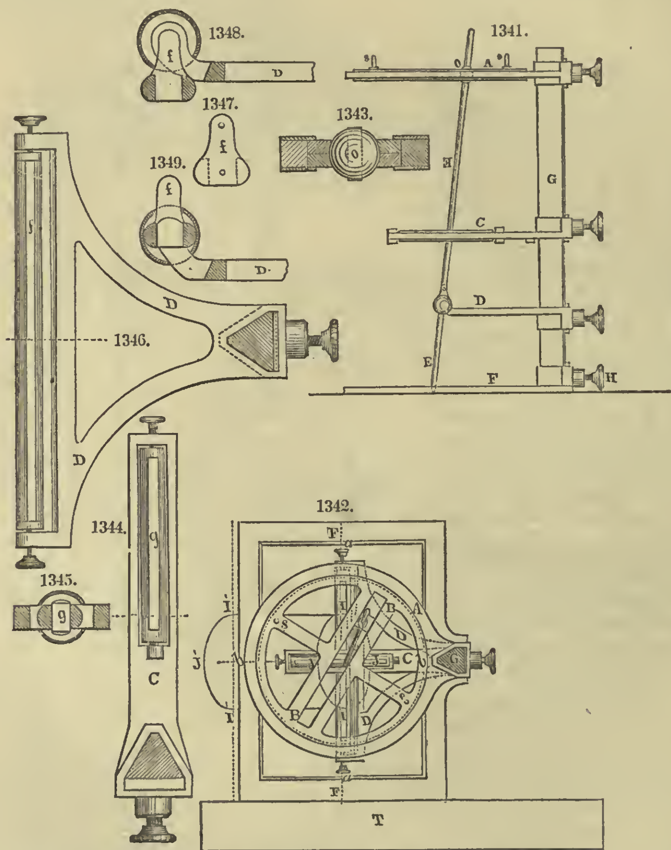
The figures I K L are accessories used for hoisting the materials, viz: I, for broken bricks; K, for water; and L, for pieces of stone for windows, chimneys, &c. M is an enlarged view of the indented wheel, and N the chain.

The advantages of this machine are, that it relieves the workman from the most toilsome part of his labor, by doing away with the practice of ascending the ladder; and it prevents, as far as possible, the accidents arising from this practice, to which he so often falls a victim. It also enables building operations to be carried on with much greater expedition than heretofore; and at the same time it diminishes the cost of such works.

Dynamical Table *of the strength of a man, showing the number of bricks that can be carried up a ladder by an ordinary laborer.*

Ft in height.	per min.	per hour.	in 10 hours.	Ft. in height.	per min.	per hour.	in 10 hours.
10	90	5400	54,000	40	22	1350	13,500
20	45	2700	27,000	50	18	1080	10,800
30	30	1800	18,000	60	15	900	9,000

ELLIPTOGRAPH. Fig. 1341 is a side elevation of the machine, showing the pencil adjusted for describing an ellipse, and Fig. 1342 is a plan agreeing to the above. Fig. 1343 is a section of the slide of the ball O which forms a universal joint for E the pencil-holder. Fig. 1344 is the arm C drawn double size. Fig. 1345 is a section of the same arm, with its rocking slide-bar *g*. Fig. 1346 is the arm D, drawn double size, with its rocking slide-bar *f*. Fig. 1347 is an end view of the bar *f*. Fig. 1348 shows the bar *f* suspended from its top centre. Fig. 1349 represents the bar *f* generally used for ellipses of ordinary proportions. A is the top frame of the instrument which carries the revolving or generating circle B. C is the moveable centre arm which determines the major axis of the ellipse. D is the bottom moveable arm which determines the minor axis. E is the pencil-holder, being a light brass tube, turned exactly parallel; its use is to hold the describing pencil, which is fitted into its lower extremity, the point being in a direct line with the axis of the holder. F is the bottom plate, into which the upright pillar G is fixed, by means of the adjusting-screw H. The method of application of the instrument is as follows:—Take a straight-edge T or T square, having previously drawn two lines at right angles across each other, for the major and minor axes of the required figure; place the bottom frame, with the centre marks *a a* on the line for the major axis, and the marks *b b* on the line for the minor axis, which marks are inside of the frame F; then bring the straight-edge T against the side of the frame F and

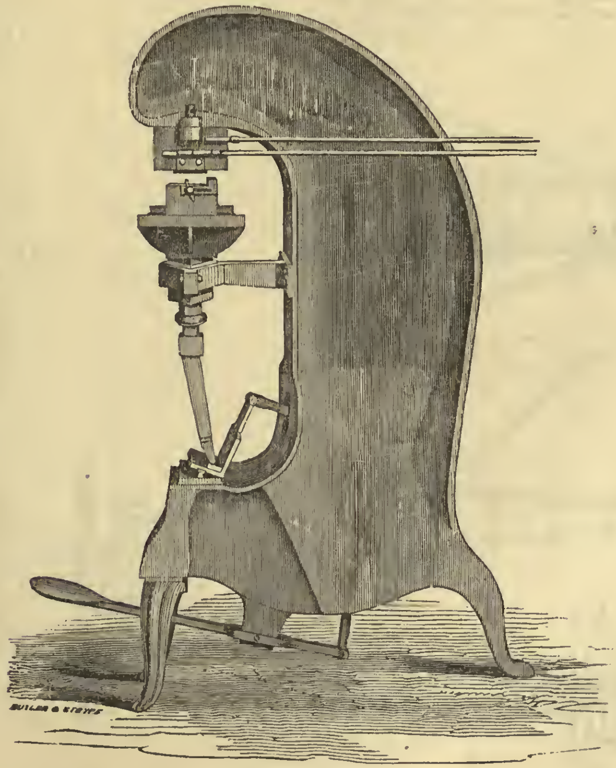


fix it. If the ellipsis required is the largest of the set, let the slide with the ball O be pushed out so far as to bring the point of the pencil to the length of the major axis I I, the generating circle having been turned round until the sliding-groove, with the ball O is parallel with the major axis, that is, when the arm C is about half height, the position shown, (this should never be higher but in extreme cases, for the lower the cross-arms C and D are kept, the steadier will be the point of the pencil;) but if by sliding out the ball O, it is not enough for the ellipsis required, the arm C must be raised until the point reaches the desired distance. When this is done, turn round the generating circle B B, until the sliding-groove of the ball O is parallel with the minor axis J J, which will be at right angles to its former position. Then slide the arm D up or down until the point of the pencil rests on the point of the minor axis, and if by turning round the generating circle B B, the pencil point touches all the four points I I J J, the instrument is correct for that proportion of the ellipsis. With this single arrangement it will now draw any number of sizes, from a mere point up to the full capacity of the instrument, by simply sliding the ball O out or in, until the point of the pencil reaches the point of either the major or minor axis required, the generating circles having been turned round to suit either of them, as before. It is

immaterial to which of the axes it is set, as the instrument will always produce the same proportions of ellipsis so long as the arms C and D are not altered. But if the major axis is required to be lengthened or shortened without changing the minor axis, the arm C must be drawn up or down so as to bring the pencil to the desired point; or if the minor axis is to be altered, the major axis remaining, the arm D must be moved up or down until the pencil again rests on the point required; the generating circle in either case having been turned round until the sliding-groove of the ball O is parallel with the axis of the ellipsis to be altered, or, which is the same, with the sliding-groove of the opposite arm. To produce the figure, nothing more is necessary than to turn round the generating circle by the finger and thumb acting on the studs S S, when the pencil point will trace the figure on the paper below; the slide of the ball O should be so tight as not to alter with the action of the pencil. The particular use of the straight-edge T, is to enable the operator to change the plane of the ellipsis and return again to the same plane; all that is required being simply to bring the points *a a* to the line of the axis required, such as I to I, &c. The closer the arms C and D are brought, the nearer will the ellipsis be to the circle, and if the rocking-bar *f* of the arm D, Figs. 1346, 1347, 1348, and 1349, is shifted to hang by the top centre, as in Fig. 1348, the two arms C and D can then be brought quite close, and the centres of suspension of both rocking-bars *g* and *f* in the arms C and D will be in the same plane, and yet both at perfect liberty to vibrate with the pencil-holder which passes through both these bars as well as through the ball O. In this case perfect circles will be produced, and if the arm D be lowered below that point in the slightest degree, the ellipsis will vary in that proportion, and so on until the arm D reaches the bottom. But if still further elongation is required, this arm D must be inverted, and the bar *f* again suspended as in Fig. 1348, when a straight line will be produced if required, by bringing the surface acted upon in the same plane with the centre of suspension of the bar *f;* and by raising the arm D in the slightest degree, an ellipsis of that proportion will be produced, and so on as the arm D is raised.

EMBOSSING MACHINE, *and Bookbinders' Arming or Stamping Press.* With this machine the pressure is applied by means of a treadle, thereby allowing the operator the use of both hands to feed and fly with; also enabling him to apply an immense pressure with but little exertion. The *form* being stationary, it may be heated by steam if required.

1350.



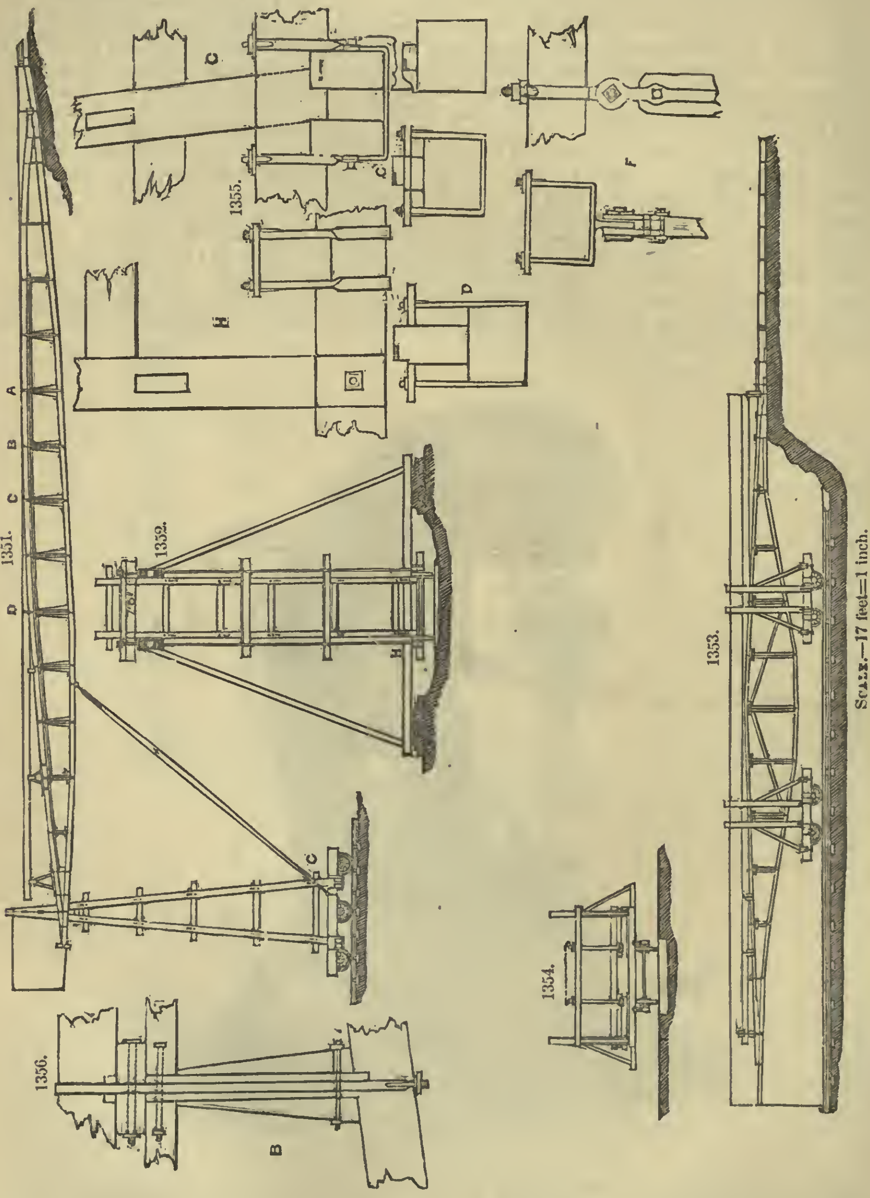
This machine is manufactured by R. Hoe & Co., New York. The embossing machines of Mr. D. Dick and of Mr. Austin, are also favorite machines with bookbinders.

EMBANKMENTS, *Moveable Machine for executing.* First employed on the St. Germain's Railway, by M. Classeyron, Engineer-in-Chief.

It consists of two trussed beams, which are laid with rails. It is placed at the head of the embankment during the course of execution, the earth wagons being run upon it after being tipped. Suppose

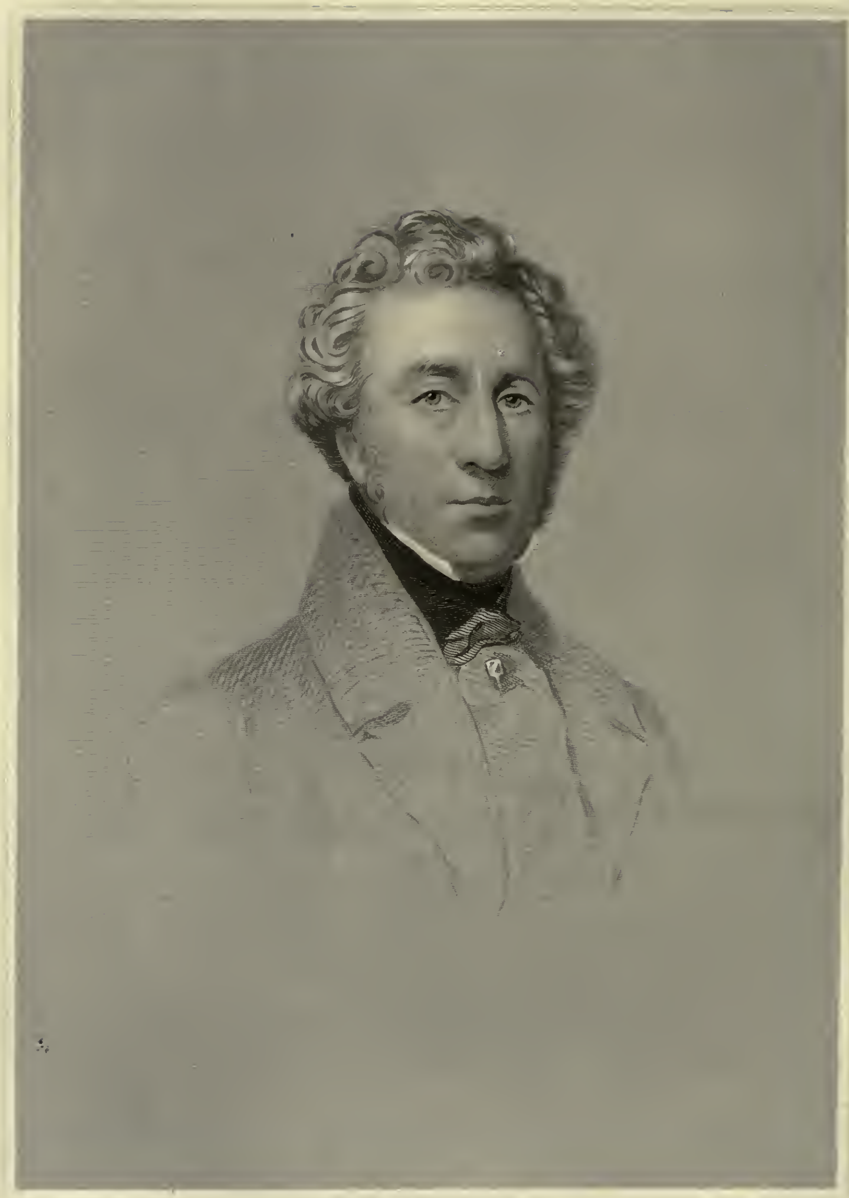
the formation of an embankment proceeding from one end of a cutting, the baleine is placed as shown in Figs. 1351 to 1356, with one end resting upon the embankment and the other laid in the same line of direction, and supported on a wheel-carriage. The carriage stands on a small auxiliary railway proceeding from the lower level of the head of the embankment, the rails being taken up at one end as the other progresses.

Upon a wagon being tipped, (at the battery head,) and the contents discharged between the rails, it is then pushed to the further end of the baleine. This course is followed with a second wagon, which is also discharged and run on the baleine, next the first, and it is continued until the baleine cannot accommodate any more, when the whole of the wagons are carried back together to the places of filling, by a horse or a locomotive engine.



The workmen move the baleines forward upon the wheels of the carriage supporting it, by crow-oars and other tools. They also raise it by ropes and pulleys to whatever height may be required at the head of the embankment.

ENAMELLING. See Glass and Porcelain.



R. NAPIER.

BUILDER OF THE ENGINES OF THE "CUNARD LINE"

ENGINES, DETAILS OF. *Pumping-Engine.*—In a pamphlet printed by Messrs. Boulton and Watt, for the use of their workmen, some time between 1782 and 1785, we have some excellent practical directions respecting the construction and management of pumping engines, the greater part of which are applicable to the circumstances of the present time.

Directions for putting the engine together.—"Having put the working-beam together, and fastened the gudgeon to it, rest it on the plummer-blocks; but do not fasten these blocks until the cylinder is fixed.

"Level the top of the stone platform, and lay the outer bottom of the cylinder down in its place, truly level, and corresponding to the holding-down screw-boxes.

"Apply the inner bottom upon the outer one, and set its upper joint level, by wedging betwixt it and the outer bottom, if it requires it; then cut out segments of pasteboard, such as is used for the boards of books, (not such as is composed of paper pasted together;) let these segments be of such thicknesses as the different parts of the joint may require, (if it be more open in some places than in others.) Soak these pasteboard segments in warm water until they become quite soft, then lay them upon boards to dry, and when quite dry put them into a flat pan with a quantity of drying linseed-oil; warm the oil until the pasteboard ceases to emit bubbles of air, but take care not to heat the oil much hotter than boiling water, otherwise it will harden or burn the pasteboard. Anoint the segments on both sides with thin putty made with fine whiting and some of the linseed-oil; let the whiting be very dry, otherwise it will be difficult to mix with the oil—and N. B., that white lead will not answer in place of it.

"You must, as much as you can, avoid using more than one thickness of pasteboard, and the segments should be a little broader than the flanch, with all the holes cut out by a chisel, but not quite so large as the holes in the iron. The segments should also be thinned at the ends where they overlap each other, so that they may form a circle of pasteboard of a uniform thickness.

"To pack the piston, take sixty common-sized white or untarred ropeyarns, and with them plait a gasket or flat rope, as close and firm as possible, tapering for 18 inches at each end, and long enough to go round the piston and overlap for that length; coil this rope the thin way as hard as you can, lay it on an iron plate, and beat it with a sledge-hammer until its breadth answers its place; put it in and beat it down with a wooden driver and a hand-mallet; pour some melted tallow all round; then pack in a layer of white oakum half an inch thick, then another rope, then more oakum, so that the whole packing may have the depth of about four inches, or only three inches if the engine be a small one. Cast segments of a circle of lead, about 12 inches long, 3 inches deep, and 1¼ inch thick, fitted to the circle of the piston, and cut down square at both ends; lay them round upon the packing as close as they can lie to one another without jamming, and screw down the piston-springs upon them; the piston-springs should be bent downwards at the end next the piston-rod, and a little mortise should be cut in the cast-iron there, for the bent-down point of each of them to lodge in, which will prevent their coming forwards to touch the cylinder. Previous to the piston being put into the cylinder the hollows among the crosses should be quite filled up with solid pieces of deal wood, put in radius fashion. The packing of the piston should be beat solid, but not too hard, otherwise it will create so great a friction as to hinder the easy going of the engine. Abundance of tallow should be allowed it, especially at first; the quantity required will be less as the cylinder grows smooth.

"The joints being all made, the regulator valves in their places, and the covers screwed on, but no water in the condenser cistern, admit steam, and when the cylinder and steam-case are thoroughly warmed, screw up the nuts of all your screws, and caulk the pasteboard or oakum of such joints as may require it, with a caulking-chisel, until you find that every thing about the cylinder is perfectly stanch; then pour three or four feet deep of water into the hot-water pump; stake down the injection and blowing-valves, and also those on the air-pump lid; then let the steam into the condenser, which will show the defects or leaks, if there be any.

"Screw on the steam-gage to the steam-case near the nozzle, and behind the engine-man's place; pour as much mercury into it as will half fill the open leg; put a float on it, broad at bottom, but very slender in the stem; cut the float or index off close to the end of the open tube, and fix a scale to it, reckoning every half-inch the float rises equal to an augmentation of the elasticity of the steam, corresponding to the supporting of a column of mercury an inch high, because the surface has sunk as much in the one leg as it has risen in the other. Solder a small copper fosset-pipe, to fit the copper communicating tube of the barometer, into the eduction-pipe, 12 inches under the fosset of the blowing-valve, and on the opposite side of the eduction-pipe; place the barometer in the door-way to the condenser on the further side from the plug-tree, so that the engine-man may see it when at his station; join the copper tube to it by pouring melted sealing-wax into the copper cup at top; fill the short leg of the barometer with mercury, within four or five inches of its top, and put a light float in it, long enough to reach to the top of its frame.

"Fill the condenser cistern, shut the lower regulator, and there being no steam in the cylinder, or its communication with the boiler being cut off, take off the bonnet or cover of the exhaustion regulator, shut that regulator, and work the air-pump by means of the brake. If then you find that air enters by the regulator, pour some water on it, and continue pumping until you have raised the barometer, i. e. sunk its float, to 27 or 28 inches; leave off pumping, and observe if the vacuum continues good, or is a long time in being destroyed. If it loses fast, seek for the leaks, which must be somewhere in the eduction-pipe, and will make a noise if touched with a wet hand, (observe if the condenser moves by the pumping, and secure it.) And having cured these leaks, you may try the tightness of the cylinder by staking the working-beam, so that the piston cannot descend; then taking the cover off the cylinder, open the exhaustion regulator, and shut the steam regulator; on beginning to pump, you will perceive if the piston be tight; if it is not it may be beat a little, and some water being thrown upon it, and on the steam regulator, whatever air enters must be by leaks, which must be sought for and cured by screwing or caulking in oakum.

"N. B. A critical tightness in the piston cannot be obtained until the engine has gone a few days

without beating it too hard, to permit the engine to move easily. When you can detect no more leaks in this way, the steam must be admitted, and the same examination made as before.

"After the engine has been set agoing, and has gone a few hours, the holding-down screws should be screwed tight, and so from time to time as they become slack; and in like manner all the other screws about the cylinder or nozzles should be screwed up as they slacken, and the joints caulked and puttied where they require it.

"*Directions for working the engine.*—To set the engine agoing, raise the steam until the index of the steam-gage comes to three inches on the scale; when the outer cylinder is fully warmed, and steam issues freely on opening the small valve at the bottom of the siphon or waste-pipe, which discharges the condensed water from the outer bottom, open all the regulators; the steam will then forcibly blow out the air or water contained in the eduction-pipe, by the blowing-valve, but cannot immediately take place if the air is in the cylinder itself; to get quit of it, after you have blown the engine a few minutes, shut the steam regulator. The cold water of the condenser cistern will condense some of the steam contained in the eduction-pipe, and its place will be supplied by some of the air from the cylinder; open the steam regulator and blow out that air; and repeat the operation until you judge the cylinder to be cleared of air; when that is the case shut all the regulators, and observe if the barometer shows that there is any vacuum in the eduction-pipe. When the barometer gage has sunk three inches, open the injection a very little, and shut it again immediately; if this produces any considerable degree of vacuum, open the exhaustion regulator a very little way, and the injection at the same time. If the engine does not commence its motion it must be blown again, and the same operation repeated until it moves. If the engine be very lightly loaded, or if there is no water in the pumps, you must be very nimble and shut the exhaustion and top regulators so soon as it begins to move quickly, otherwise it will make its stroke with great violence, and perhaps do some mischief. To prevent which, open the top and exhaustion regulators only a little way and put pegs in the plug-tree, so that they may be sure to shut these regulators long before the piston comes to the bottom.

"If there is much unbalanced weight on the pump-end, you must also take care to put a peg in the ladder which guards the steam regulator lever, so as to allow that regulator to open only a little way, and so to lessen the passage for the steam when it enters to fill the cylinder, otherwise the rods, &c., at the pump-end may descend too fast and be prejudicial; if you find, after a few strokes, that the engine goes out too slow, the steam-regulator may be opened wider. In order to regulate the opening of the exhaustion regulator you should have pieces of board, of various thicknesses, to put under the weight which pulls it open, by means of which it may be made to open more or less at pleasure, and the top regulator may be managed in the same manner.

"Should the engine work with too great violence, on account of its being underloaded, you may correct it by giving the top regulator a lesser opening, and shutting it at such a part of the stroke as will just give the piston sufficient force to come to the bottom. Whenever the top regulator is used the exhaustion regulator should be thrown fully open every stroke, in order to give a free exit to the steam, on which a great part of the good effects of the top-regulator depends.

"The engine should always be made to work full stroke, that is, until the catch-pins come within half an inch of the springs on each end, which is easily managed by an attention to the pegs. Care must be taken that the piston rise high enough in the cylinder, when the engine is at rest, to spill over into the perpendicular steam-pipe any water which may be condensed above it; for if any water remain there, or in any other part of the cylinder while it is working, it will very much increase the consumption of steam. When the engine is to be stopped shut the injection and secure it; put a peg in the plug-tree to prevent the exhaustion regulator from opening, and take out the peg on the other side so as to allow the steam regulator to open and to remain open: otherwise you may have a partial vacuum in the cylinder, and it may be filled with water from the injection or leakages, which is a troublesome accident. The top regulator should also be open while the engine stands.

"When an engine is in tolerably good order it will bear to stand ten minutes, and go to work again without blowing afresh; and though it has stood two or three hours, if there has been any steam issuing from the boiler, and no air has been admitted into the cylinder, it will generally go off with once blowing for about a minute.

"If you find, after following the above directions, that the engine does not go to work, shut the exhaustion regulator and give some injection; if it then makes no vacuum, it is likely there are air-leaks about the eduction-pipe; if it does make a vacuum which remains but a short time, it may be owing either to air or water leaks; these may be distinguished by blowing as before, and shutting the lower regulator for about a minute without giving any injection. If, upon opening it again, it throws out a good deal of water at the blowing-pipe before it blows steam, it is certain that it either has some leak in the condenser under water, or that the injection or blowing valve does not shut close; if they are found to shut close, every joint should be examined, and also the valve at the foot of the eduction-pipe.

"If, after blowing as before, you find that immediately on opening the exhaustion regulator a quantity of air is thrown out at the blowing-valve, the leak is in the eduction-pipe, somewhere between the surface of the water in the cistern and the nozzle The particular place of these leaks may be found by emptying the cistern of water, putting three or four feet deep of water into the hot-water pump, and staking down the blowing and injection valves with those on the air-pump lid; then, if steam be admitted into the eduction-pipe it will come out at the leaks and point them out. If not found out in this way, apply the brake to the air-pump, taking care first to put some water on its bucket, and then by working that pump by hand, you will probably, on an attentive examination, observe where air goes in, which may be known more distinctly by wetting the place suspected.

"If upon shutting the lower regulator and making a vacuum in the exhaustion-pipe by pumping, or by injection, you find the vacuum continues good for a considerable time, then the fault does not lie in the eduction-pipe, but in the nozzle or joint of the cylinder bottom, where it must be sought for.

"In these examinations by pumping it is proper to take off the bonnet or cover of the exhaustion

regulator, and to examine if air enters at that regulator; if it does, and only in small quantity, throw some water on the regulator while you are examining the eduction-pipe; and when the leak is suspected to be in the bottom joint of the cylinder, or in the lower nozzle, you must throw some water on the steam regulator and also on the piston, then, by pumping and strict examination, you will soon find where the air enters. When you are examining the tightness of the piston by pumping, you must stake the beam, so that the piston may not descend.

"If in course of working you do not find the vacuum keep good, and the engine goes sluggishly, or stops and requires to be blown frequently, you must examine whether an uncommon quantity of air or water issues at the hot-water pump, or if any comes out at the valves on the air-pump lid; if the quantity of air is great, the engine has some air leak; and if the quantity of water be great, and is cooler than usual, it proceeds from a water leak in the condenser; if the quantity of water be great, and at the same time very hot, it proceeds from a bad piston, or from the steam regulator not shutting close.

"The engine will also go badly if the air-pump or water-pump buckets or clacks strip the water, that is, let it pass by them. You will know if this be the case with the water-pump bucket by observing whether the water follows down after it at the return of the stroke, and leaves a part of the pump empty; if it does not, either the bucket strips the water or the engine receives water in some way which it ought not.

"Attention ought to be given to feeding the boiler in a regular manner, that it may not be spoiled, nor steam wanted. When there is too much water in the boiler the engine will not work regular, and if there is too little the sides of the boiler will be burnt by the flame in the flues. If by accident it should at any time run a little too low, the feed should be augmented so as to fill it gradually; for if you run in too much at once, you will check the steam, and stop the engine; but if it be run very low, stop the engine, open the puppet clack, and fill the boiler from the pool or reservoir, if you have one; otherwise fill it by working the air-pump, having first staked down the valves on its cover and opened the injection-valve. In working the engine the steam ought to be strong enough to make the index of the steam-gage stand half an inch high at least, otherwise air will enter at the joints of the boiler, &c., and spoil the vacuum, so as to cause a good deal of trouble to get quit of it again. Therefore if you perceive the steam-gage to be lower, stop the engine until it rises again. By a little attention you will find the proper opening of the feeding-cock for any rate of working.

"Let all the coals employed to feed the fire be thoroughly watered just before they are thrown on, as that will prevent their being swept into the flues by the draught of the chimney.

"The fire should be kept of an equal thickness and free from open places or holes, which are extremely prejudicial, and should be filled up as soon as they appear; if the fire grows foul and wants air, by clinkers collecting on the bars, they must be got out with a poker, but the fire should be as little disturbed in that operation as possible, and the greatest care taken not to make any coals or coke fall through which are not thoroughly consumed; it is very common for a fourth of the whole coals to be wasted in this manner by mere carelessness. When the fire is newly made the damper should be raised a little, so as to let off the smoke freely, but should be let down to its proper place so soon as the smoke is gone off. The air door in the chimney should be always open more or less; it prevents the flame from being sucked up the chimney, and very considerably increases the effect of the coals. Once a month the boiler and flues ought to be cleaned, or oftener if the water be very subject to incrust the boiler. Every morning the ashes ought to be taken out, the engine-house swept clean, and a view taken of every part of the engine, to see that nothing be working out of its place or want oiling. Particular attention ought be paid to the bolts and cutters of the great chains and piston-rod, so that none of them get loose.

"An engine, when in good order, ought to be capable of going so slow as one stroke in ten minutes, and so fast as ten strokes in one minute; and if it does not fulfil these conditions, somewhat is amiss that can be remedied.

"The hot water should issue of the heat of 96° of Fahrenheit's thermometer, that is, blood warm, when the engine is in excellent order, and should never exceed the heat of 110°, unless when the injection or cold water is hotter than 70°, and in that case the vacuum will not be good.

"*To make putty for making or repairing the joints.*—Take whiting, or chalk finely powdered, dry it on an iron plate or in a ladle until all the moisture be exhaled; then mix it with raw linseed-oil, and beat or grind it well, adding more oil or whiting until it be of the consistence of thick paint, and perfectly free from lumps or inequalities.

"For some purposes, where the putty is wanted to dry and to be very sticky, use painters' drying oil, which is made by boiling the oil with a small quantity of litharge or red-lead.

"Where the putty is wanted to continue always soft, mix about two ounces of butter or common salad-oil with each pound or pint of the linseed-oil. This soft putty is principally useful in the caulked joints of the eduction-pipe above water. N. B. White-lead will not answer in place of the whiting.

"No wet cloths should be suffered to be laid on the cylinder, boiler, or steam-pipes, and every part containing steam should be guarded as much as possible from the influence of cold air or water.

"The proper grease for the piston and cylinder stuffing-box is melted tallow, and for the chains, gudgeons, &c., common Spanish olive-oil, which, for some uses, may be thickened by dissolving some tallow or butter in it by means of heat. Linseed-oil should never be used as grease, as it dries and creates more friction than would have been without it. Hogs' lard, or train-oil, if applied anywhere about the cylinder, or where it is hot, will thicken like linseed-oil. When the oil or grease about the great chains, or any of the working parts, grows clotted or very thick, it should be scraped off before new grease is added.

"An improvement has lately been made in the covering of boiler tops. The setting being built up to nine inches above the flues as usual, a course of horse or cow dung, three inches thick and well beat, is applied to the boiler top; on the outside of that is laid some good lime mortar, about an inch in thickness, to which is applied a course of bricks flatwise, with their ends upwards; on the outside of that

another course of bricks (also laid in good mortar) in the same position, but so as to break joint with the first course; in which manner the covering is carried on until the whole top is covered, taking care to leave an opening for the man-hole; every flanch may be thus covered, and when well done it effectually makes the top steam-tight, and also defends it from cold and rain, so that a boiler-house is not necessary. The mortar employed must be such as stands water.

"*Additional observations.*—Instead of using painters' drying-oil to make the joints with, take good raw or unboiled linseed-oil, put it in an iron pot, place it over a gentle fire, (out of doors, but protected from rain,) let it be watched as it heats, as it is very liable to boil over; when it boils make the fire more moderate, but continue to heat the oil, until upon dropping some of it upon a cold stone or piece of iron, you find it is, when cold, of the thickness of thick tar or treacle. The pasteboards for the joints are to be soaked in this oil warm, or painted over with it, and laid in a hot place to suck it up; and it is also to be used to make the putty with.

"The oakum with which the joints are caulked should be well smeared with the strong or thick boiled oil mentioned in these additional directions. If the under side of the pipe of the inner bottom does not fit close to the lower edge of the opening made for it in the outer bottom, that is to say, if the space left there for pasteboard or caulking be wider than one quarter of an inch, a piece of hammered iron an inch and a half broad must be forged of such thickness as to fill up the space, so as to make it tight by the help of a thickness of pasteboard above it, and another below it. Lead ought not to be used in these cases, as its expansion and contraction by heat and cold are too great. Instead of putting a prop from the nozzle to the ground, it is found better to put a balance beam off sideways under the floor with a short upright having a flat end to take a broad bearing under the nozzle. The weight of the balance should not support more than two-thirds of the weight of the nozzle.

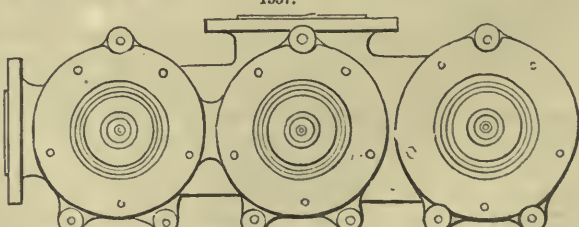
"Some people use a plaited rope to make the joint of the cylinder lid, which is a bad practice; for though a plaited rope may make a joint apparently steam-tight, yet it has been found by experience, that such joints are not air-tight; but when, by the working of the top regulator, a partial vacuum is produced in the upper part of the cylinder, they permit some air to enter imperceptibly, and without noise, which, of course, passes to the condenser, and by persons that are not aware of this circumstance, may be thought to enter at some air leak in another place. We therefore recommend that this joint be always made with pasteboard and putty; and that a strict attention be paid to the tightness of the stuffing-box, wherever the top regulator is used."

In the Cornish engines great diminution in the consumption of fuel has taken place, chiefly by the larger application of the principle of expansion. An 85-inch cylinder engine, erected at the United Mines in 1840, reached in 1842 an average duty of 107 millions of pounds raised 1 foot high with a bushel of coals. In this engine the pressure of the steam is 40 lbs., and it is cut off at one-tenth or one-twelfth of the stroke. To diminish the risk of fracture in engines using such high steam, the double cylinder engine is employed. The small cylinder here stands on top of the large one, and the same piston-rod passes through both. The same number of valves too that is used in common pumping-engines, suffices in this modification of the double cylinder plan.

† The Cornish engines are provided with a steam jacket. The clothing applied to the cylinder is very various; a common plan is to enclose the cylinder in a brick wall, leaving a space between them; to plaster the wall, and coat it with timber. The cylinder cover and cylinder bottom are usually made hollow, and filled with steam: they are then carefully coated with non-conducting materials.

The main beam of the engine usually consists of two cast-iron plates, bolted together, and armed with projecting horns to catch the spring beams, should the piston be disposed to strike the bottom of the cylinder. From the beam hangs the plug-rod, by which the valves are moved by means of some such arrangement as that shown in Fig. 1358, which differs in some respects from the Cornish form. The valves of the Cornish engine erected by Mr. Hosking are shown on a large scale in Figs. 1357, 1359, and 1360. These valves are of the equilibrium description. Figs. 1357 and 1359, the valve to the left is the governor-valve, by the adjustment of which the flow of steam to the cylinder is regulated; the centre valve is the steam-valve; and the valve to the right is the equilibrium-valve. Fig. 1360 represents the eduction-valve, which, it will be remarked, is larger than the others, so as to afford a free exit for the steam into the condenser. Three-quarters of a square inch per horse power is a common size for the steam-valve in rotative engines, furnished with spindle-valves; and a square inch and a quarter per horse power is a common size for the exhaustion-valve.

1357.

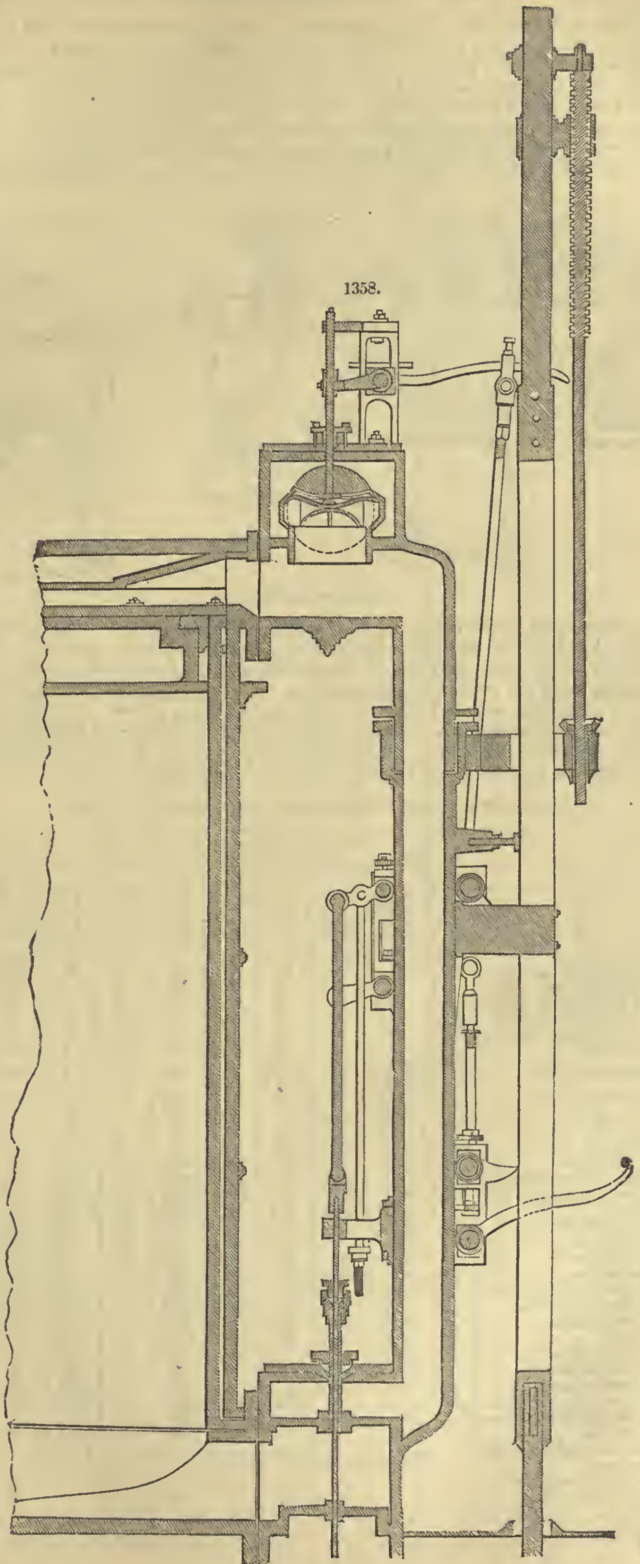


SCALE.—4 feet=3 in.

The plunger-pump is the pump universally used in the Cornish mines, and it is much preferable to the lifting-pump, as it can be packed afresh, or the packing may be tightened, with much greater facility than can be done in the case of a lifting-pump, while the friction is at the same time less. The shaft is divided into a succession of lifts, in which the water of the lowest lift is delivered to the pump next above it, and so on in succession until the water reaches the surface. The plunger-pump is used in all these lifts except the lowest, where the lifting-pump is used, with the view of obviating inconvenience, should the water from derangement in the machinery, or otherwise, rise so high in the mine as would make the valves and barrel of a forcing-pump inaccessible, and also on account of the facilities afforded

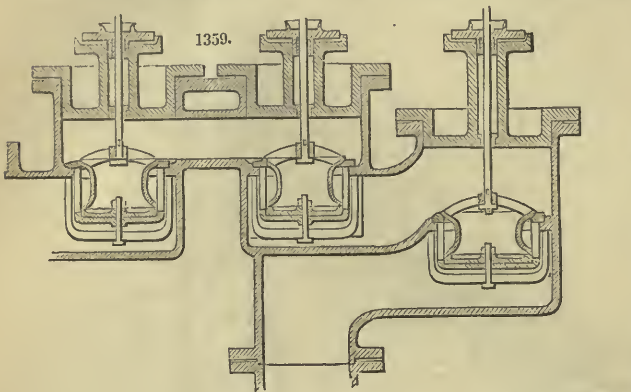
* Bourne on the Steam Engine. † See Cornish Engine.

1358.

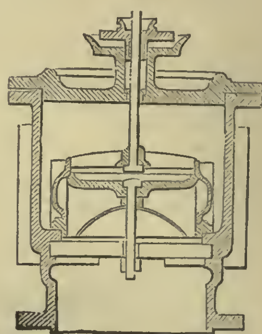


by the lifting-pump in the drainage of the water as the mine is sunk deeper. The plunger-pump obviates the necessity for as large a counterweight as would otherwise be necessary; for the force of the engine is expended in lifting the pump-rods, and the water is forced out by the weight of the pump-rods in their descent. The pump-rods of some of the engines, however, are too heavy for the engine to lift, and part of the weight has to be taken off by one lever or more, provided with counterbalance weights, placed either at the surface or in some convenient side excavation. The main pump-rod of Davy's engine at the Consolidated Mines, is one-third of a mile in length, and weighs 95 tons. The other rods weigh 40 tons, making a total weight of 135 tons, of which 39 only are wanted to balance the water in the

1359.



1360.



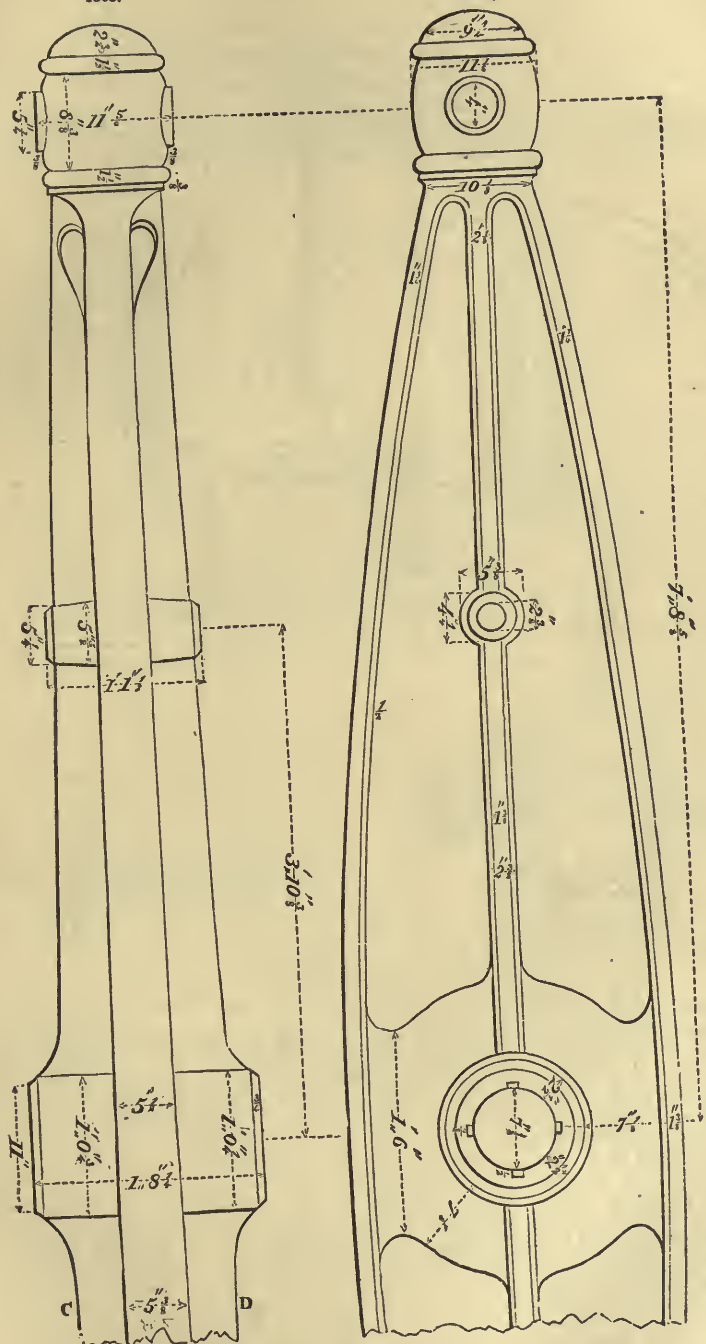
SCALE.—$\frac{3}{8}$ inch=1 foot.

pump, and the greater part of the remaining 96 is balanced by weighted levers. The main pump-rod is usually composed of balks of Memel timber, and at intervals down the sides of the shaft projecting pieces are bolted on, which catch upon suitable timbers let into the sides of the shaft, to prevent the rod from descending too far in the event of fracture above. The rod is guided at intervals by appropriate frames. There is something rather primitive in these expedients, and it is not improbable that the whole of this cumbrous apparatus will hereafter be superseded by machinery operating by atmospheric pressure, whereby the pump-rods will be rendered superfluous, or else by the centrifugal pump; and a small engine, working at a quick speed, will suffice for working such an apparatus.

TABLE OF OBSERVATIONS UPON TEN CORNISH ENGINES.

		CONSOLIDATED MINES.						UNITED MINES.			
		Taylor's engine.	Davy's engine.	Job's engine.	Woolf's engine.	Bawden's engine.	Pearce's engine.	Cardozo's engine.	Eldon's engine.	Loam's engine.	Hosking's engine.
Dimensions of engine.	Diameter of cylinder—in inches	85	80	65	90	90	65	90	30	85	85
	Stroke of piston—in feet	10	$11\frac{1}{3}$	9	10	10	9	9	9	10	10
	Diameter of steam-valve—in inches	12	13	9	8	8	7	10	5	10	12
	" equilibrium-valve—in in.	16	18	12	16	16	12	13	7	16	16
	" exhaustion-valve—in in.	20	24	14	19	19	14	15	10	19	19
Dimensions of boilers.	Number of boilers	4	3	2	4	3	3	3	1	3	3
	Length of boilers—in feet	3·36 / 1·40	37	31 / 32	35	36	36	36	36	1·32 / 2·38	44
	Diameter of boilers	$6\frac{1}{2}$	7	$6\frac{1}{2}$	$6\frac{1}{4}$	$6\frac{1}{4}$	$6\frac{1}{4}$	$6\frac{1}{4}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$
	" tubes	$3\cdot3\frac{3}{4}$ / 1·4	$4\frac{1}{3}$	$3\frac{3}{4}$	$3\frac{3}{4}$	$3\frac{3}{4}$	3	$3\frac{3}{4}$	4	4	4
	Length of fire-bars	4	4	4	4	4	4	4	4	4	4
	Total area of fire-bars	63	52	30	60	45	45	48	16	48	48
	Heating surface exposed to flues	3781	3151	1598	3481	2694	2694	2694	941	2952	3451
	Water space—in cubic feet	2467	2025	1033	2140	1650	1650	1650	579	1706	2085
	Steam space— "	735	580	315	608	468	468	468	178	528	645
Temperatures observed.	Open air—Fahrenheit	57°	57°	—	57°	57°	51°	55°	56°	51°	55°
	Engine-house—Fah.	—	—	—	—	—	67°	—	55°	63°	66°
	Ashes over boiler—Fah.	80°	80°	81°	98°	98°	97°	88°	99°	79°	82°
	Cylinder cover—Fah.	111°	90°	102°	126°	96°	109°	94°	98°	90°	84°
	Middle of cylinder clothing—Fah.	W 77°	W 76°	B 95°	B 102°	B 140°	—	B 79°	W 60°	W 67°	W 68°
	Clothing of steam-pipe—Fah.	79°	—	—	130°	95°	—	140°	97°	80°	82°
	Condensing-water—Fah.	64°	84°	58°	115°	110°	57°	60°	61°	63°	60°
	Hot well—Fah.	98°	100°	91°	140°	140°	97°	104°	94°	102°	96°
	Height of condenser barometer—in in.	$27\frac{1}{4}$	$27\frac{1}{2}$	—	$25\frac{1}{2}$	—	—	—	—	—	$27\frac{1}{2}$
	Number of plunger-pumps	9	12	2	7	8	9	8	1	5	5
	" bucket-pumps	2	2	—	1	2	2	2	—	4	3
	Water load per sq. inch of piston in lb.	11·46	13·12	8·78	11·56	8·3	16·8	11·5	17·96	11·95	13·58
	Proport'n of stroke where steam cut off	1-5th	1-5th	—	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{3}$	2-11ths	—
	Strokes per minute	$8\frac{1}{2}$	$7\frac{1}{2}$	—	9	9	10	$8\frac{1}{2}$	9	8	7
	Proportion of duration of in-door to out-door stroke	4 : 7	5 : 8	4 : 7	5 : 7	5 : 7	5 : 6	4 : $6\frac{1}{2}$	4 : 7	1 : 2	4 : $7\frac{1}{4}$
	Grease used per day—in lbs.	12	12	10	12	12	10	12	6	12	12
	Oil used per day—in pints	1	1	1	1	1	1	1	$\frac{1}{2}$	1	1
	Men employed	4	4	3	4	4	3	4	3	4	4
	Boys employed	3	3	3	4	4	3	3	—	3	3

1363. 1362.

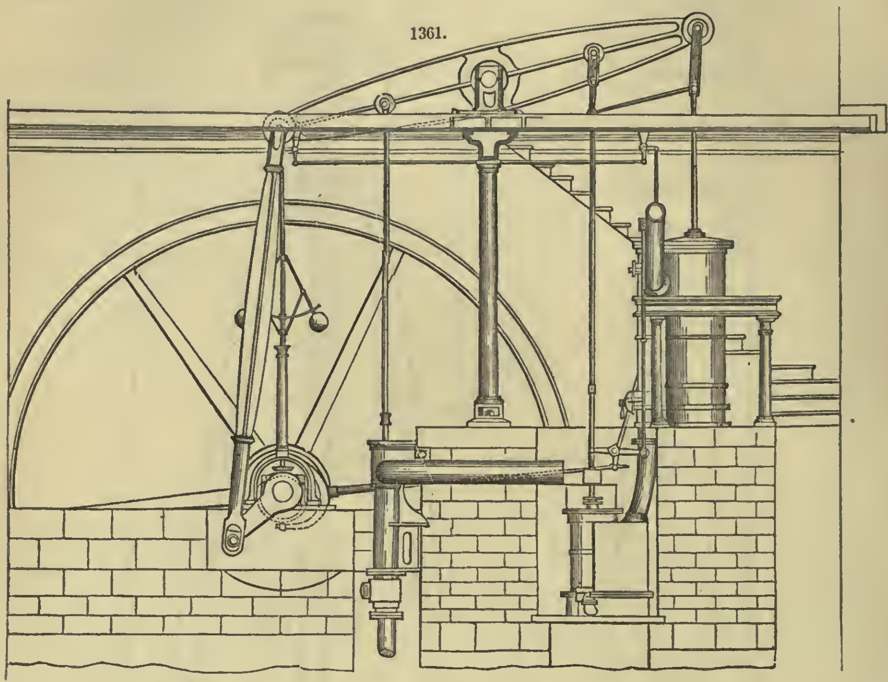


Working-beam.—SCALE.—¼ inch=1 foot.

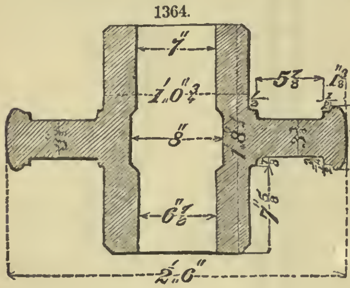
A bushel of Welsh coal now used in Cornwall weighs 94 pounds.

Rotative engines.—A rotative engine of Messrs. Caird's, is represented in Fig. 1361, which is a general elevation.

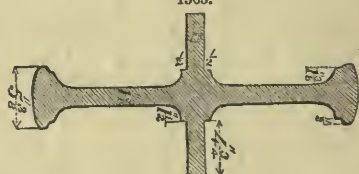
1361.



1364.



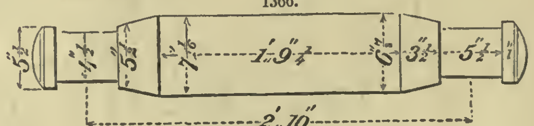
1365.



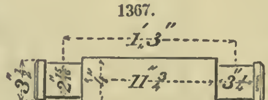
Scale.—¾ inch=1 foot.

Figs. 1362 and 1363 are enlarged views of the working-beam, which is of cast-iron; and Figs. 1364 and 1365 are sections of the same. The sizes of this beam agree, with tolerable nearness, with those given in our tables of dimensions. The depth of beam at the centre is usually about equal to the diameter of the cylinder, and the depth at the ends is generally made about one-third of the depth of the beam at the centre. The length of the beam is generally about three times the length of the stroke, and the thickness 1-108th of the length. By the thickness is meant the mean thickness: the edge-bead is usually 1½ time the thickness of the web.

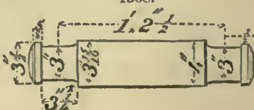
1366.



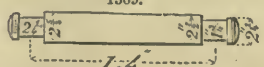
1367.



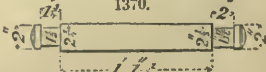
1368.



1369.



1370.



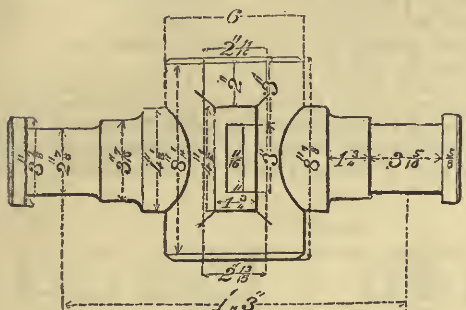
Scale.—¾ inch=1 foot.

Fig. 1366 is the cast-iron main centre of the working-beam; Fig. 1367 is the cast-iron stud for the main links; Fig. 1368 is the connecting-rod stud, of cast-iron; Fig. 1369 is the wrought-iron stud for the air-pumps; Fig. 1370 is the wrought-iron stud for the hot and cold water pumps.

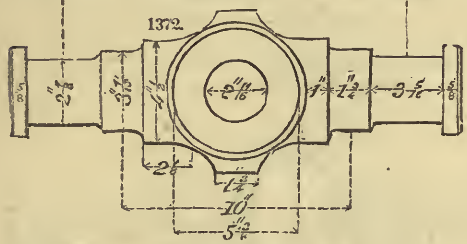
The diameter of the end studs of the beam is generally made about 1-9th of the diameter of the cylinder when the studs are of cast-iron, and 1-10th of the diameter of the cylinder when they are of wrought-iron; but the larger proportion is preferable, as the wear of the brasses is then less rapid. It is a common fault to make bearings too small, from their proportionment being viewed with reference only to strength, whereas it should also be viewed with reference to wear.

Figs. 1371 and 1372 are views of the piston-rod clutch or cross-head. The piston-rod passes into the round hole in the centre of the clutch, and the main links encircle the projecting bearings, and join the clutch with the main beam. Fig. 1373 represents the cross-head gibs and cutter.

1371.

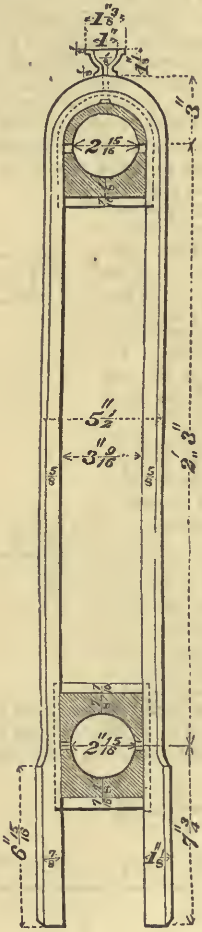


1372.

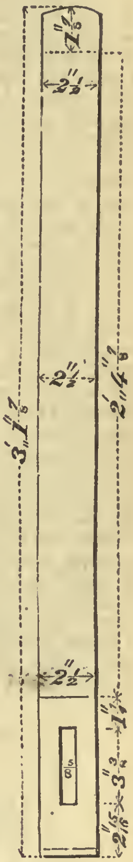


SCALE.—1½ inch=1 foot.

1374.

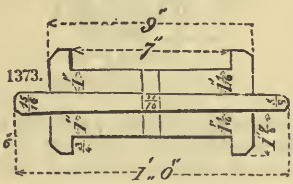


1375.



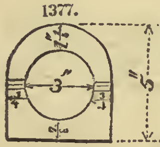
SCALE.—1½ inch=1 foot.

1373.

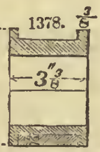


SCALE.—1½ inch=1 foot.

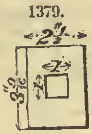
1377.



1378.

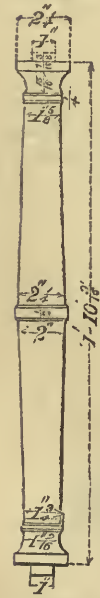


1379.



SCALE.—1½ inch=1 foot.

1376.

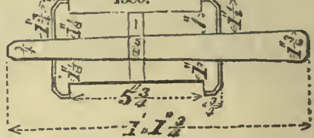


1½ inch=1 foot.

Figs. 1374 and 1375 represent the main links; Fig. 1376, the pillar of the main link, which is interposed between the upper and under brasses; and Figs. 1377, 1378, and 1379 the upper brass and pillar-plate of the link. Fig. 1380 represents the gibs and cutter of the main links. The sectional area of the main links is usually made about 1-113th of the area of the piston, that of the piston-rod being 1-100th. To find the proper sectional area of the main links, a common rule is to divide the square of the diameter of the cylinder by 144. The length of the main links is usually about the same as the length of the crank, which is half the stroke. The main beam is always somewhat longer than the distance between the cylinder and crank centres, and at the cylinder end the perpendicular centre line divides the versed sine equally. The angular motion of the beam is about 38° during the whole stroke. The length of stroke is the chord of the arc the centre of the end pin describes, and the versed sine represents the amount of deviation from the perpendicular, which is called the vibration of the beam. The beam being three times the length of the stroke, the dis

tance from the main centre to the end stud is one and a half times the length of the stroke, and with these proportions the end stud will deviate from the perpendicular one inch for every foot of stroke. To find the amount of vibration of the end stud: from the square of the radius in inches described by the stud, subtract the square of the length of the crank in inches; extract the square root of the remainder, which deduct from the radius in inches. To find the proper distance between the main centre and the centre of the cylinder: add the above-mentioned square root to the radius of the lever in inches; half their sum will be the horizontal distance in inches.

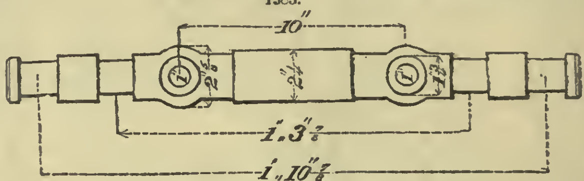
1380.



Scale.—1½ inch=1 foot.

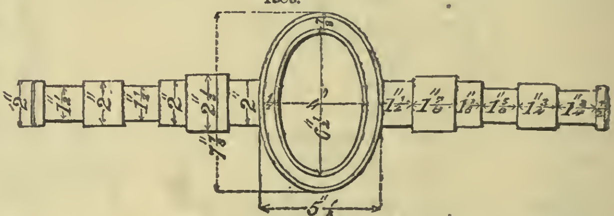
The main centre of a land-engine beam is usually fixed in with keys; the other centres are sometimes fixed with keys, and at other times they are ground in, which appears to be the preferable practice. The beam is set upon its edge on two blocks of wood; a straight-edge is applied to ascertain if it is nearly straight, and if bent or twisted it is brought straight by being hammered with the face of the hammer, though this practice weakens the beam if carried far. A cross-piece of wood is put into each main-centre hole, upon which the central point is marked; the beam is plumbed, the end centres are put through, staked with wedges, and levelled by means of a short level with two legs passing down from the edge of the beam. The lengths from the main centre are next ascertained to be right, and the main centre is then put in, using the end centres as points to measure from. Finally, the keys are fitted. This is the mode of procedure when the holes for the centres are not bored out. It is expedient to put a centre line on the edge of the beam to fix the position of the studs laterally, and this is generally done. The force acting at each end of an engine-beam may be taken at 14 pounds per circular inch of the piston, or, if the beam be supposed to be supported at both ends, it may be taken at 28 pounds per circular inch acting at the centre. The depth of the beam at the ends being one third of the depth at the middle, to find the dimensions at the middle, divide the weight in pounds acting at the centre by 250, and multiply the quotient by the distance in feet between the supports. To find the depth, the breadth being given, divide this product by the breadth in inches, and extract the square root of the quotient, which is the depth. It is expedient, however, to make main beams stronger than is indicated by any of these rules, as a higher pressure of steam is now used almost universally than was employed by Mr. Watt. In our rules for the dimensions of beams at the centre, the resulting figures represent the web of the beam, or the dimensions within the beads, if the pressure of the steam be above that of the atmosphere.

1385.



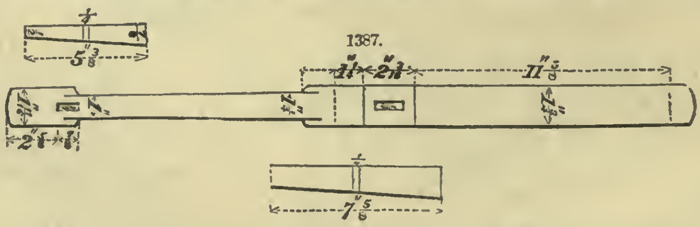
Scale.—1½ inch=1 foot.

1386.

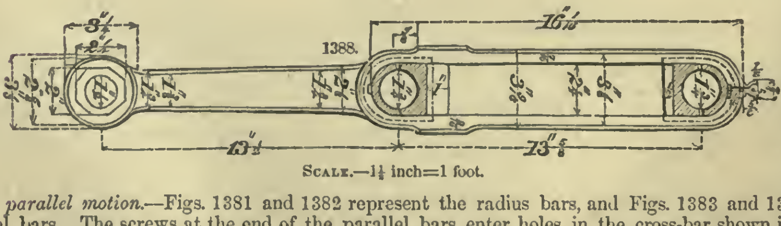


Scale.—1½ inch=1 foot.

1387.

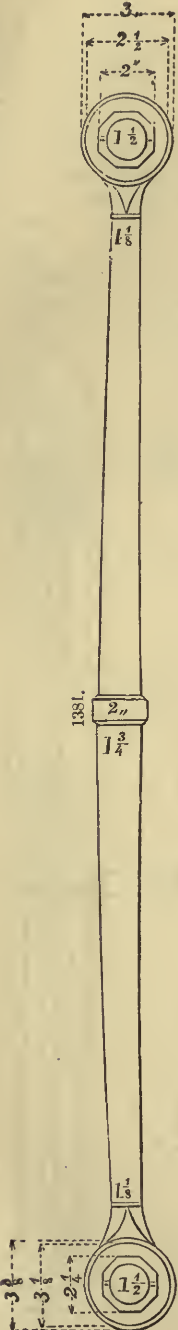


1388.

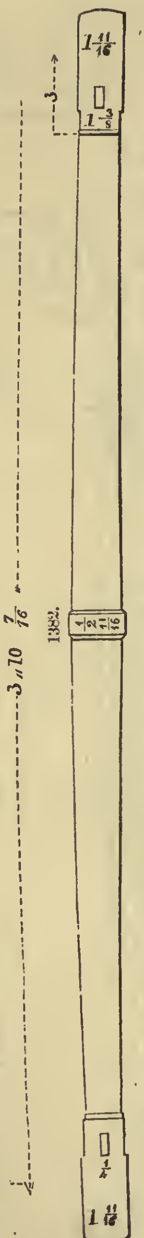


Scale.—1½ inch=1 foot.

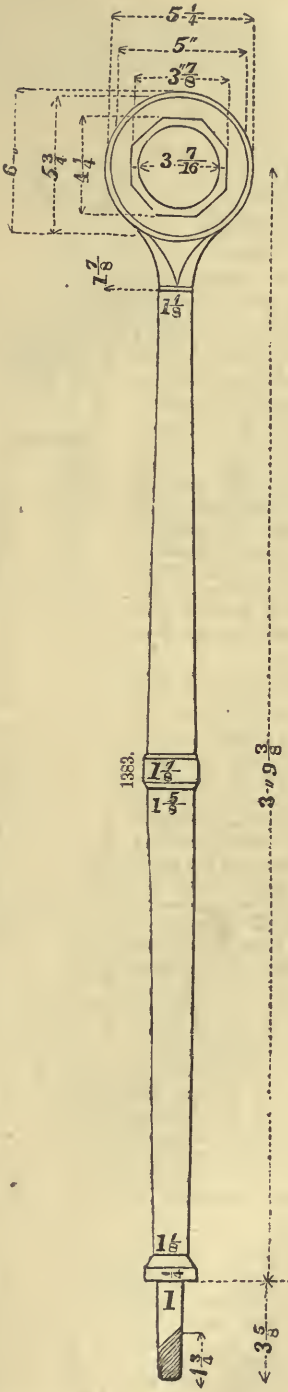
The parallel motion.—Figs. 1381 and 1382 represent the radius bars, and Figs. 1383 and 1384 the parallel bars. The screws at the end of the parallel bars enter holes in the cross-bar shown in Figs. 1385 and 1386, and to the exterior bearings of the same cross-bar the radius-bars are attached, the other ends of those bars being attached to studs fixed to the spring beams in the line of the piston-rod.



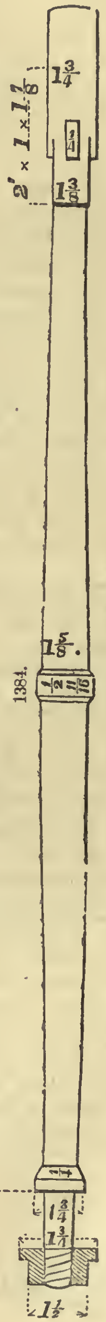
1381.



1382.



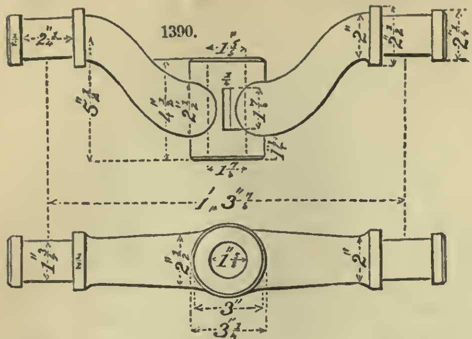
1383.



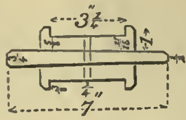
1384.

Scale.—1½ inch=1 foot.

1390.



1389.



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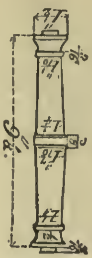
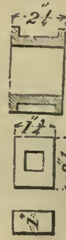


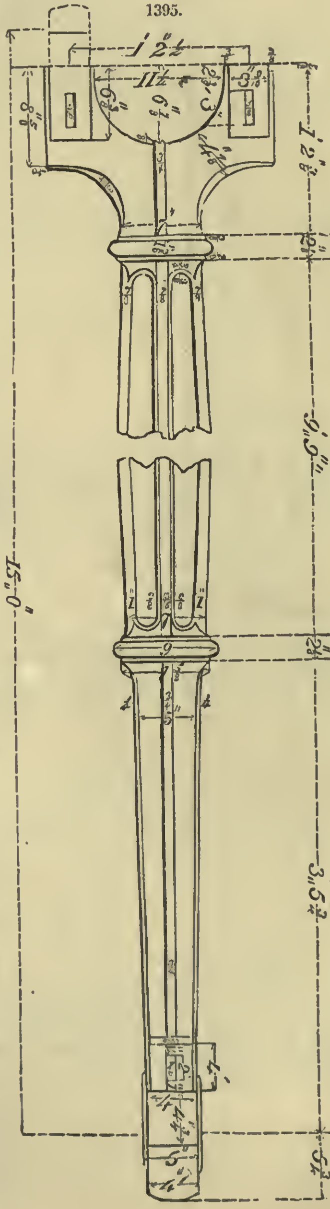
1393.



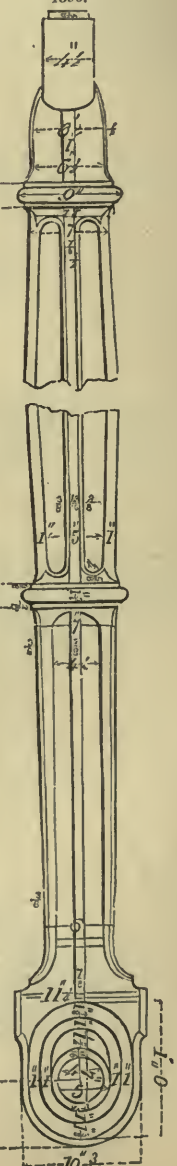
1392.

SCALE.—1½ inch=1 foot.

1395.



1396.

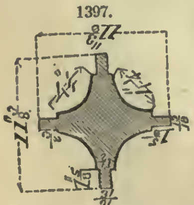


Figs. 1387 and 1388 represent the back links, the upper brass of which encircles the air-pump stud in the beam; the middle brass receives the cross-head on the top of the air-pump rod, and the lowest brass connects with the cross-bar of back links, Fig. 1386, through the oval hole in which the air-pump rod passes. The sectional area of the back links is made the same as that of the air-pump rod, which is one tenth of the diameter of the air-pump, or one twentieth of the diameter of the cylinder. The sectional area therefore of the two back links taken together is equal to the area of a circle one-twentieth of the diameter of the cylinder; but in practice they are generally made of somewhat stronger proportions.

The best proportionment of the parallel motions of land engines, and that now followed universally, consists in making the radius and parallel rods of exactly the same length, and this length equal to half the radius of the great beam. The stud from which the back links are hung is in this case situated midway between the main centre and the end stud of the beam, and the studs in the spring beams round which the radius bars move, are in the same vertical line as the centre of the cylinder. To find, therefore, the right position for those studs, measure down perpendicularly from the centre of the end stud, when the beam is level, to a distance equal to the length of the main or back links, and at this distance draw a horizontal line on the inner sides of the spring beams. Then set off from the main centre on this line the distance between the main centre and centre of the cylinder; the point of intersection is the right position of the studs in the spring beams to which the radius or bridle rods are attached.

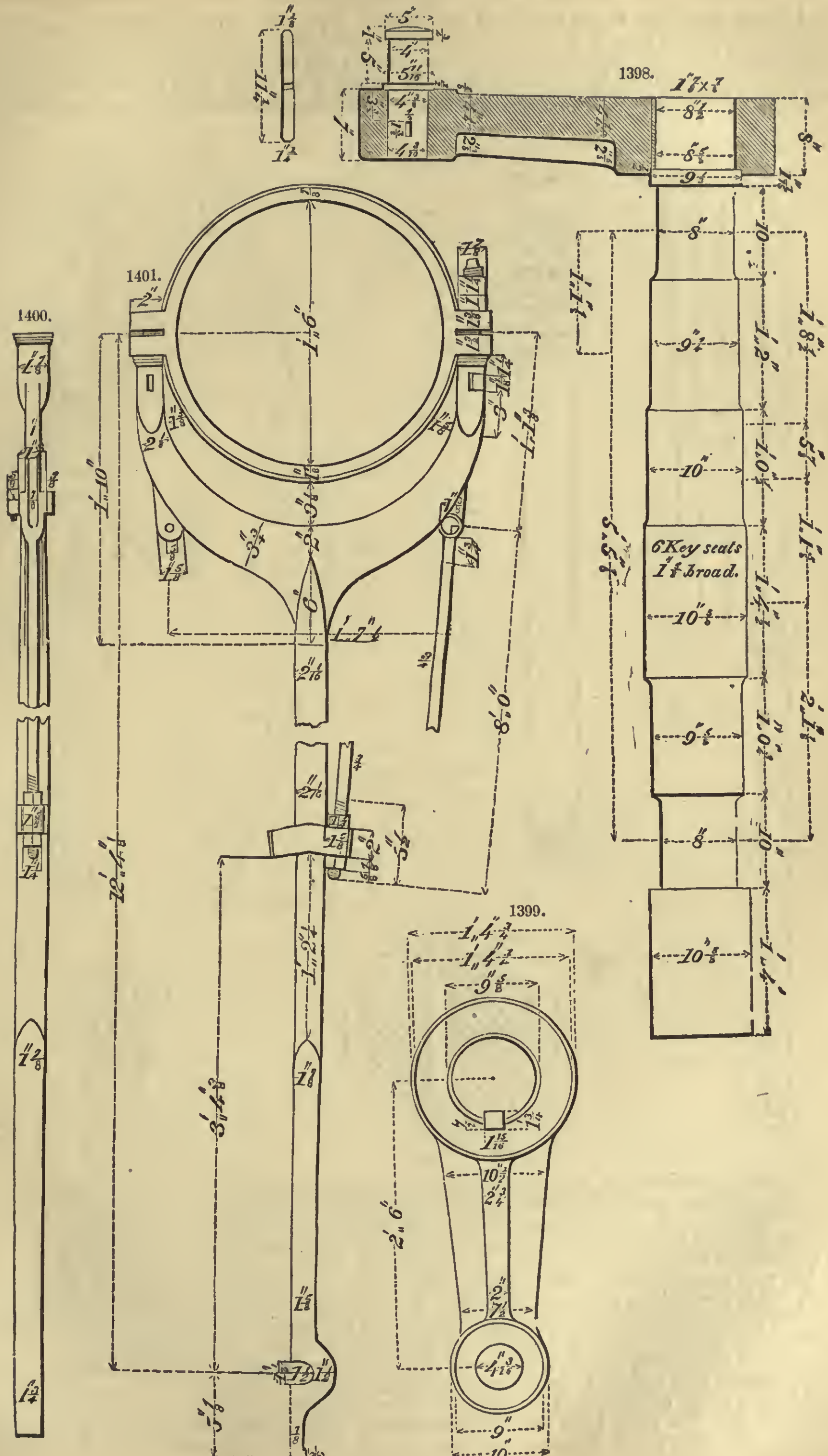
The back links and the main links are always of the same length, and are now generally made half the length of the stroke, or the length of the crank, as we have already stated. The air-pump cross-head is in-

1397.



SCALE.—1½ inch=1 foot.

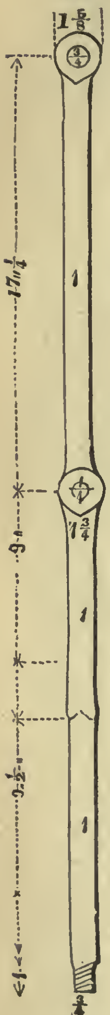
1398. 1399. 1400. 1401.



SCALE.—1 inch=1 foot.

serted in the back links at the middle of their length. This point in the back links moves, it is obvious, in the vertical line, for as the top of the links follows the motion of the main beam, and the bottom that of the radius bars, which have the same radius and the same length of motion as the stud in the beam from which the links are suspended, the central point of the links will have motion in a curve equally removed from that of each end, which will be a straight line very nearly. The line traced

1402.



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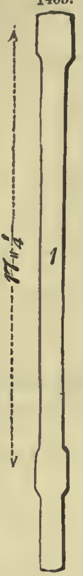
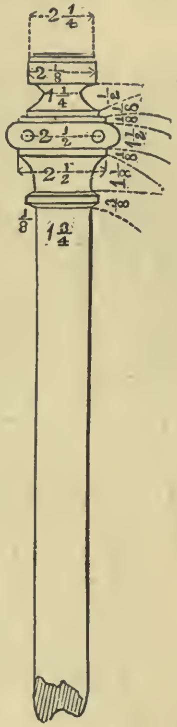


1404.



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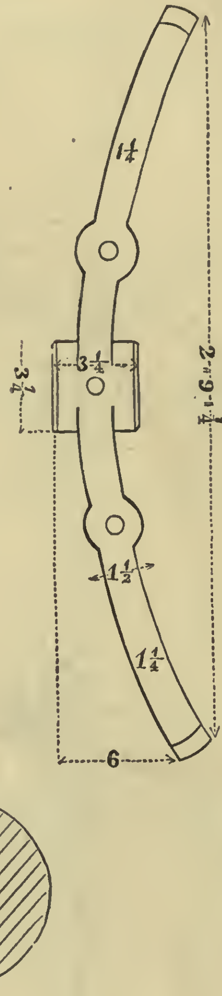

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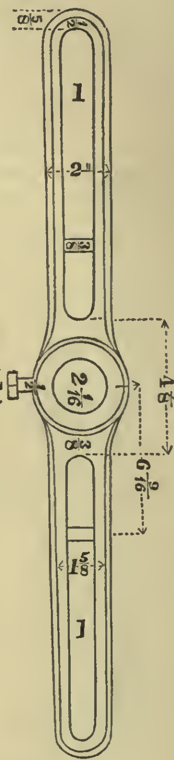

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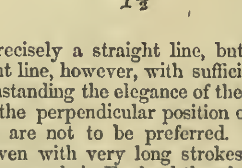

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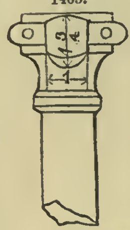

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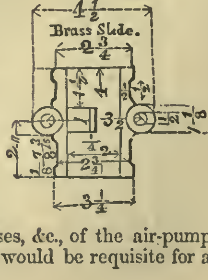


by the parallel motion is not precisely a straight line, but a species of S curve; it approaches to a straight line, however, with sufficient nearness for every practical purpose. Notwithstanding the elegance of the parallel motion, as an expedient for maintaining the perpendicular position of the piston-rod, it is questionable whether guides are not to be preferred. In this country they are very generally used, even with very long strokes and very short beams; and in some of the steam vessels in England they have been substituted with advantage. The adjustment of parallel motions is a difficult task; and unless the parallel motion be very true it will be difficult to keep good packing in the stuffing-box, and the cylinder will speedily be worn oval.

Figs. 1389 and 1390 represent the air-pump cross-head, which fits into the central brasses of the back links. Fig. 1391 is the pillar which fits between the brasses; and Figs. 1392, 1393, and 1394, are different views of the brasses, &c., of the air-pump cross-head. The parts appertaining to the air-pump are made of the size that would be requisite for a cylinder of the same diameter.

Figs. 1395 and 1396 are views of the connecting-rod, which is of cast-iron. Malleable iron connecting-rods are now coming into use for land engines, and they are in every way preferable. When the connecting-rod is of cast-iron, of the form represented in the figure, the breadth across the arms of the cross is made about 1-20th of the length of the rod; the sectional area at centre of rod 1-28th of the area of the cylinder, and the sectional area at ends of rod 1-35th of the area of the cylinder. Fig. 1397 shows the form of sectional area at centre. The length of the connecting-rod is generally made about three times the length of the stroke. The diameter of the crank-pin is about one-sixth of the diameter of the cylinder, and is generally made of cast-iron in land engines. The gudgeons of water-wheels are generally loaded with about 500 pounds for every circular inch of their transverse section, which is nearly the proportion which obtains in the end studs of engine-beams, but the main centre is usually loaded beyond this proportion. To find the proper size of a cast-iron gudgeon adapted to sustain a given weight, multiply the weight in pounds by the intended length of bearing expressed in terms of the diameter, divide the product by 500, and extract the square root of the quotient, which is the diameter in inches. For malleable iron the operation is the same, but the divisor may be made 1,000 instead of 500. These strengths are not intended to resist torsion, but are those proper for gudgeons. Experiments upon the force requisite to twist off cast-iron necks show, that if the cube of the diameter of the neck in inches be multiplied by 880, the product will be the force of torsion in pounds which will twist them off when acting at 6 inches radius. The strength for cast-iron crank-shafts may be determined by multiplying the square of the diameter of the cylinder in inches by the length of the stroke in feet, multiplying by the decimal ·15, and extracting the cube root of the product, which is the proper diameter of the shaft-neck in inches. This rule has reference not merely to torsion, but also to the strength as a gudgeon necessary to sustain the fly-wheel.

Messrs. Fenton and Murray use the following rule for determining the weight of the fly-wheel:—Multiply the number of horse power of the engine by 2,000, and divide the product by the square of the velocity of the circumference of the fly-wheel in feet per second; the quotient is the proper weight of the fly-wheel in hundred-weights. To find the weight of the rim of a fly-wheel in pounds, multiply the mean diameter of the rim in feet by the area of its transverse section in square inches, and multiply the product by 9·817 pounds. This gives the weight of the rim in pounds when the sectional area is determined. Mr. Farey gives the following rule for determining the proper quantity of cast-iron in a fly-wheel in cubic feet:—Multiply the mean diameter of the rim by the number of its revolutions per minute, and square the product for a divisor; divide the number of horse power exerted by the engine by the number of strokes the piston makes per minute; multiply the quotient by the constant number 2,760,000, and divide the product by the divisor found as above. The quotient is the requisite quantity of cast-iron in cubic feet to form the fly-wheel rim.

In large engines each arm is cast separate, and after having been fitted to the central boss, the rim of the wheel is fitted to the arms in segments. In small engines, an arm and a segment are generally cast together. In mill engines it appears expedient to work with a short stroke and rapid piston, whereby the fly-wheel is made more effectual, or a smaller one will suffice.

We do not approve of the plan of putting cast-iron cranks on hot, as the eye is liable to be cracked in the process: it is preferable, we conceive, to grind them upon the shaft, and then to fix them by means of a strong square key, such as that shown in Fig. 1399. In cranks which are put on hot it is expedient to recess the crank-eye a little, so as to enable the collar upon the shaft to enter it, as the crank contracts sideways in the act of cooling; and unless the collar be recessed a space will be left between it and the crank-eye, which will be a disfigurement. The crank-pin is made slightly taper, and is fixed in by means of a key.

Figs. 1400 and 1401 are representations of the eccentric-rod, and Figs. 1402 to 1409 are views of the several parts of the governor. We have given rules for determining the proportions of governors, and the arrangement of the parts here figured will be apprehended by a reference to Fig. 1402. The upright revolving spindle on which the collar shown in section, Figs. 1405 and 1406, slides, and the curved guide, Figs. 1408 and 1409, is fixed. From the top of the spindle, the arms, Fig. 1402, are suspended, with the balls at the end, the arms moving in the slit in the curved guides, Figs. 1408 and 1409. The divergence or collapse of the balls causes the collar to slide up or down on the spindle; and through a slit shown in the spindle, (which is hollow,) this movement is communicated to a rod sliding within it, which, by a suitable attachment, moves the throttle-valve.

The speed given by Mr. Farey, in a table, from which the annexed is an extract.

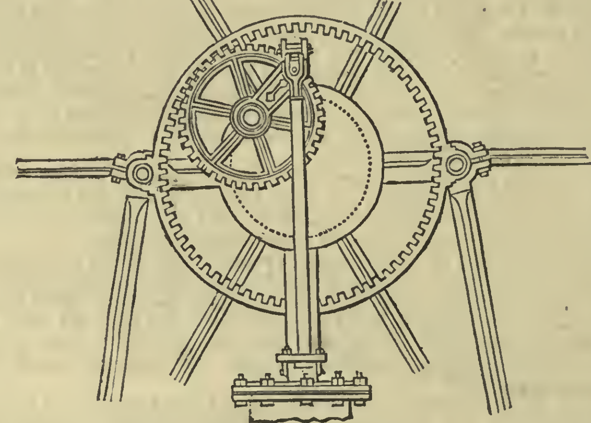
Horse power.	Diameter of cylinder.	Length of stroke in feet.	Number of strokes per minute.	Speed in feet per minute.	Effective pressure per square inch in lbs.
4	12	3	29	174	6·8
8	16	4	24	192	6·84
12	19	4	25	200	6·88
16	21¾	4½	23	207	6·91
20	23¾	5	21½	215	6·92
30	28¼	6	19	228	6·92
40	31½	7	17½	245	6·92
50	35⅛	7	17½	245	6·94
60	38½	7	17½	245	6·94
70	40¾	8	16	256	6·94
80	43½	8	16	256	6·94
90	46⅛	8	16	256	6·94
100	48⅝	8	16	256	6·94

In this table the pressure is taken to vary slightly with the size of the engine; but Messrs. Boulton and Watt now adopt a uniform pressure of 7 pounds on the square inch, as a preferable element of computation. The speed of the piston in feet per minute is about 128 times the cube-root of the stroke; and the nominal horse power of an engine may be found by multiplying the square of the diameter of the cylinder in inches by the cube-root of the stroke in feet, and dividing by 47. To find how many millions of pounds are raised 1 foot high by the consumption of a bushel or 84 pounds of coal:—Divide 166·32 by the number of pounds of coal consumed per hour by each horse power; the quotient is the number of millions of

pounds raised 1 foot high by the consumption of 84 pounds of coal. A bushel of Newcastle coal will weigh about 84 pounds, but the Welsh coal is heavier.

If a cubic inch of water be supposed to produce a cubic foot of steam, and the latent heat of steam at 212° be taken, with Mr. Watt, at 960°, or, in other words, the cubic foot of steam be supposed to contain as much heat in the latent form as would raise the temperature of the cubic inch of water, if it could be prevented from expanding, 960°, then the sum of the latent and sensible heats will be represented by 1172°. The temperature of the water discharged by the air-pump is about 100°, which, taken from 1172°, leaves 1072°, which must be taken up by such a quantity of cold water that its temperature will not rise above 100°. If the temperature of the injection water be 50°, then the difference between that and 100°, viz. 50°, is available for the absorption of the heat; and 1072 divided by $50 = 21{\cdot}44$, which is the number of times the quantity of injection water must exceed the quantity of water in the steam. To condense a cubic inch of water, therefore, in the shape of steam, 21·44 cubic inches of injection water are necessary; but inasmuch as the water may not always be as cold as 50°, Mr. Watt's practice was to allow a wine pint, or 28·9 cubic inches of injection water for every cubic inch of water converted into steam. The capacity of the cold-water pump is usually made from one thirty-sixth to one forty-eighth of the capacity of the cylinder. The injection orifice should have an area of about one fifteenth of a square inch per horse power. The capacity of the hot-water pump should be about one 240th of that of the cylinder, supposing that the engine is double-acting, and the pump single-acting. The air-pump is usually made half the diameter of the cylinder, and half the stroke, or one eighth of the capacity. The power requisite to work the air-pump is from one thirtieth to one fortieth of the power of the engine. The openings through the foot and delivery valves are made of about one fourth of the area of the pump. The internal diameter of the steam-pipe may be found by dividing the horse power by 0·8, and extracting the square root of the quotient. We shall reserve what we have to say on the subject of bolts until we come to speak of the holding-down bolts of marine engines.

1410.



There are many other kinds of parallel motion besides those which we have mentioned, but there are none of them of sufficient importance to justify a lengthened description. Fig. 1410 represents a species of parallel motion invented by Mr. James White, and published in his "New Century of Inventions," in 1801. It depends on the principle that an encloidal curve, formed by one circle rolling within another, becomes a straight line when the diameter of the outer circle is just twice that of the inner one. A large wheel, with teeth on its inner circumference, is fixed on a frame concentric with the axis and circle of the crank. A wheel with external teeth is fixed freely on the crank-pin and the point of attachment of the piston-rod. By this arrangement the small wheel is compelled, by the pressure of the piston-rod upwards, to roll round the great circle, ascending on the one side, and descending on the other, so that the distance of the end of the piston-rod from the point of contact of the circles is always equal to the distance of the circle from the diameter. The fault of this species of parallel motion is, that the socket in the centre of the revolving wheel is exposed to a strain equal to twice that on the piston, and which it cannot conveniently be made long enough to resist, so that it is liable to break or speedily shake loose. In the plate of direct-action engines, various modifications of the parallel motion will be observed. In the Gorgon engine, by Messrs. Seaward, the parallel motion is formed by the application of a radius-bar to the air-pump lever, whereby one radius is made to counteract the other,—the centre of the lever resting upon a jointed pillar, in order to enable the cylinder end of the lever to move up and down in a vertical line. This species of parallel motion is sometimes made with a horizontal slide for the centre to move in, instead of a vibrating pillar or link; but a slide works slack sideways, and is not satisfactory in practice. The combination might be improved by causing the sliding ends of the rods, which in some cases are used instead of a lever, to work into stuffing-box tubes hung on a centre, so as to enable them to swivel. The rods, so soon as any wear took place, could be tightened afresh by screwing up the packing.

Marine engines: Cylinder.—In the marine engine the cylinder-bottom is more frequently cast in, than in land engines, and a plug of metal is fitted into a hole in the centre of the bottom, which is left

to allow the boring-bar to pass through. It is necessary that the cylinder should be bolted very firmly to the sole-plate, as in engines which exhaust at the under side of the valve-casing, an air-tight joint has to be made between the sole-plate and the part of the cylinder-bottom next to the valve. A cylinder of about 6 feet diameter is usually made about 1½ inch thick, and the metal should be hard as well as solid. Messrs. Maudslay's practice in side-lever engines is to cast the cylinder-bottom in, up to 60 inches diameter, and above that size they prefer casting the cylinder open at the bottom, and making the bottom out of the sole-plate. A projection is cast on the sole-plate, to go a certain distance into the cylinder, with a space hollowed out for the cylinder-port. The bottom joint should not be of rust, but metal to metal—the bottom flange of the cylinder and the place on which it stands on the sole-plate being both faced in the boring-mill. The cylinder cover should fit so nicely as to be tight, by interposing a piece of lead or a ring of wire gauze, smeared with white or red lead. In oscillating engines the cylinder bottom is generally cast in, whatever be the size of the cylinder.

The valve-casing should be attached to the cylinder by means of a metallic joint, or, in other words, by fitting the surfaces so accurately that a little red-lead interposed will make them tight. The valve-casing can thus be easily removed at any time to repair the valve faces; whereas, if the joint of the casing be of rust, the removal of the casing is an operation of much difficulty. The attachments of the cylinder to the diagonal stay are very generally made too small; that is, the surface is too small, and the flange too thick. A very thick flange cast on any particular part of a cylinder endangers the soundness of the cylinder by inducing an unequal contraction. It is much the best way to make the flange for the framing thin, and the surface large. The bolts, too, should be turned bolts, and nicely fitted. Some persons make them with a nut at both ends, the body of the bolt being made with a little taper; and the nut which answers to the head is screwed up after the conical part of the bolt has been drawn into the hole by the nut at the point. The object of this plan is to facilitate the fitting; but if the fitting be well done, it is unimportant whether it is done in this way or any other.

Cylinders are not now usually made with steam-casings, yet experiment has satisfactorily proved that there is a loss of power consequent on their relinquishment. It is not very easy to discern the cause of this loss, as there is more radiating surface in the casing than in the cylinder; yet the existence of the loss is very certain. Mr. Watt, in some of his early trials, discontinued the steam-jacket; and he found the consumption of fuel to be materially increased. He therefore again resumed it, but it has been again discarded in most of the modern engines, except those of the Cornish construction. Escape-valves, for letting out any water that may enter with the steam, are now usually employed in marine engines: they may in most cases be applied conveniently to the ports of the cylinder, as shown in the details of engines of the West India packets, and may be kept shut by a spring, in the same manner as the safety-valve of a locomotive. Escape-valves should be placed on that side of the cylinder which is nearest the side of the ship; so that the attendants may not be scalded by the issuing water if the engine primes. The escape-valve is shown beneath the "Plan of Cylinder" in the West India mail engine details; and to those details the remarks which follow are to be understood to refer, except where specified to the contrary. In boring cylinders of 74 inches diameter, the boring-bar must make one revolution in about 4½ minutes, so that the cutters will move at the rate of about 5 feet per minute. In boring brass, the speed must be slower: the common rate at which the tool moves in boring brass air-pumps is about 3 feet per minute. If this speed be exceeded the tool will be spoiled, and the pump made taper. The speed proper for boring a cylinder will answer for boring the brass air-pump of the same engine. A brass air-pump of 36½ inches diameter requires the bar to make one turn in about 3 minutes, which is also the speed proper for a cylinder 60 inches in diameter. To bore a brass air-pump 36½ inches in diameter requires a week, an iron one requires 48 hours, and a copper one 24 hours. In turning a malleable iron shaft, 12¾ inches in diameter, the shaft should make about five turns per minute, which is equivalent to a speed in the tool of about 16 feet per minute. A boring-mill, of which the speed may be varied from one turn in six minutes to twenty-five turns in one minute, will be suitable for all ordinary wants that can occur in practice.

Piston.—The proportion of taper given to the piston-rod where it fits into the piston, in the West India mail engines is a good one; if the taper be too small, the rod is drawn through the hole, and the piston is split. Small grooves are turned out of this piston-rod above and below the cutter-hole, and hemp is introduced, in order to make the piston-eye tight. Most piston-rods are fixed to the piston by means of a gib and cutter, as shown in the figures of details, but in some cases the upper portion of the rod within the eye is screwed, and it is fixed into the piston by means of an indented nut. This nut is in some cases hexagonal, and in other cases the exterior forms a portion of a cone, which completely fills a corresponding recess in the piston. But nuts made in this way become rusted into their seat after some time, and cannot be started without much difficulty. Messrs. Miller, Ravenhill and Co., fix in their piston-rods by means of an indented hexagonal nut, which may be started by means of an open box key. The thread of the screw is made flat upon the one side, and much slanted on the other, whereby a greater strength is secured, without any disposition to split the nut. When pistons are made of a single ring, or of a succession of single rings, the strength of each ring is tested previously to its introduction into the piston, by means of a lever loaded by a heavy weight. The old practice was to depend chiefly upon grinding, as the means of making the rings tight upon the piston or upon one another; but scraping is now chiefly relied on. A slight grinding, however, with powdered Turkey stone appears to be expedient, which may be most conveniently accomplished by setting the piston on a revolving table, and holding the ring stationary by a cross-piece of wood while the table turns round. Pieces of wood may be interposed between the ring and the body of the piston, to keep the ring nearly in its right position; but these pieces of wood should be fitted so loosely as to give some side-play, else the ring will wear itself into a groove on the piston. Messrs. Penn grind their cylinders after they are bored, by laying them on their side, and rubbing a heavy piece of lead, made to the curve of the cylinder, and smeared with emery and oil, backwards and forwards by hand, the cylinder being gradually turned round, so as to subject every part successively to the operation. The pistons are also ground

into the cylinders with great care, so that they are perfectly tight from the commencement. Messrs Penn's piston for oscillating-engines has a single packing ring, with a tongue-piece, as in Messrs. Maudslay's and Messrs. Miller's arrangements. The ring is packed behind with hemp-packing, and the piece which covers the joint is made of sheet-copper, and is indented into the iron of the ring, so as to offer no obstruction to the application of the hemp. The ring is ground to the piston only on the under edge: the top edge is rounded from the inside to a point, and the junk-ring does not bear upon it, but the junk-ring squeezes down the hemp-packing between the packing-ring and the body of the piston. The metallic packing of the piston consists of a double tier of rings, cut into numerous segments. We approve of the plan of adding a nut to the top of the piston-rod, in addition to the cutter, for securing the piston-rod to the cross-head, as shown in Fig. 1411, where the piston-rod is 7 inches in diameter, and the screw 5 inches: the part of the rod which fits into the cross-head eye, is 1 foot 5½ inches long, and tapers from 6½ to 6 13-16th inches diameter. The proportion of taper is a good one: if the taper be less, or if a portion of the piston-rod within the cross-head eye be left untapered, as is sometimes the case, it is very difficult to detach the parts from one another.

1411.

Cylinder cover.—The cylinder cover in plate of details is cast close, and a few holes are left for taking out the core by, which holes are afterwards plugged up. An annular recess is left in the under side of the cover, for the accommodation of the heads of the piston-bolts. The gland of the stuffing-box is shown on a larger scale on the same plate. Fig. 1412 represents the stuffing-box of the Don Juan steamer, cylinder 68 inches diameter. This appears to us better than that of the West India packets: there is a great advantage in a deep stuffing-box, especially in the case of vessels intended to perform long voyages. Fig. 1413 represents the cylinder cover of a Cornish engine. The stuffing-box is provided with a lantern brass, into which steam is admitted by a small pipe. There is packing both above and below the lantern brass, to prevent any leakage of air by the stuffing-box; for even if the packing be defective, it will be steam that leaks in, which is condensable; and such a leak, though it will increase the consumption of fuel, will not diminish the power of the engine. It is the usual practice to interpose between the cylinder cover and the cylinder flange a gasket-ring as a joint; but a joint of this kind leaks air imperceptibly, and it is better to make the surfaces very true, and to interpose either a ring of sheet-lead or a little red-lead putty. It appears expedient to us that all marine engines should be furnished with steam-jackets, and should also be furnished with spaces in the cover and cylinder-bottom for the admission of steam. Large engines, too, we conceive should be fitted with the lantern brass stuffing-boxes.

1412.

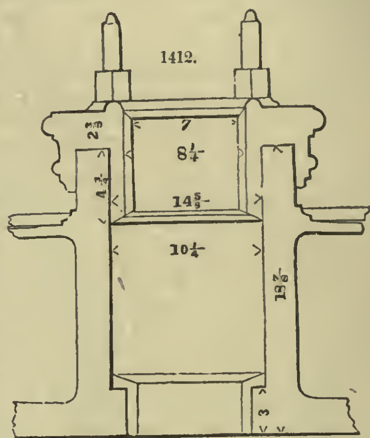
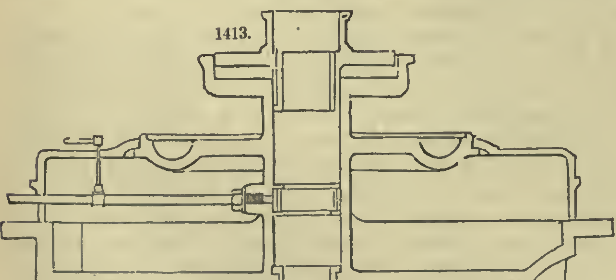
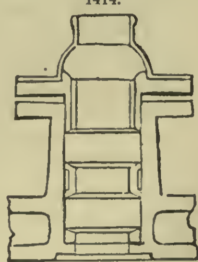


Fig. 1414 represents the stuffing-box of the Trident, the engines of which are of the oscillating kind by Messrs. Boulton and Watt. The extra depth of this stuffing-box is necessary to counteract the tendency to wear oval. This tendency has not been found to occasion much inconvenience in oscillating engines. In engines with the ordinary parallel motion the stuffing-box has a tendency to wear oval, which may be perceived if attention be paid to the setting of the parallel motion. If the piston be moved through a stroke, the gland will be found to move easily upon the piston-rod at some points, and be jammed up tight in the stuffing-box at other points of the stroke; inequalities which clearly show

1413.



1414.

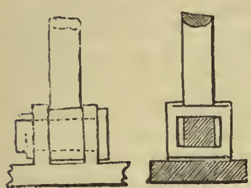


SCALE ⅛ inch=1 foot.

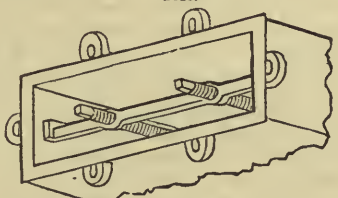
the existence of a very sensible deviation from a perfectly vertical motion. The brass dome attached to the gland and embracing the rod, is an excellent addition; it keeps the grease employed to lubricate the rod, from being split, and prevents grit and dust from getting into the gland, whereby in common engines the rod is frequently much scratched and injured. Metallic packing in the stuffing-box has been used in some engines, consisting in most instances of one or more rings, cut, sprung out, and slipped upon the piston-rod, before the cross-head is put on, and packed with hemp behind. This species of packing answers very well when the parallel motion is true, and the piston-rod free from scratches, and it accomplishes a material saving of tallow. In some cases a piece of sheet-brass, packed behind with hemp, has been introduced with good effect, a flange, notched to permit the bending, being turned over on the under edge of the brass, to prevent it from slipping up or down with the motion of the rod.

Slide-valve.—The slide-valve represented in the plate of details is that known as the long D. The valve-rod is attached to a cross-bridge in the plane of the under face, and the spring upon the rod is sufficient to allow the valve to be tightened up as the face wears. In short D valves, where the valve-rod is very short, the eye which attaches the valve to the rod has to be made oblong, Fig. 1415, or else the holes of the casing-cover have to be made oval, so as to enable the valve-cover to be advanced nearer to the cylinder, as the valve face wears. The valve-packings are introduced by doors at the back of the valve-casing, and are pressed by blocks, of which one is shown in the same plate as the valve. This block, it will be remarked, is in three pieces, which are tongued to one another; it is pressed forward by means of screws, which pass through a cross-bar extending across the packing-port, Fig. 1416, the ends of which rest in two angular lugs cast therein. The purpose of this bar is to prevent the strain requisite for tightening the packing from being thrown upon the packing-door, which would spring it out, and might cause the joint of the door to leak. In some cases the screws by which the packing is pressed, pass through the door, and are made tight by a jam-nut, with a recess, into which a turned part of the nut enters, as shown in Fig. 1417; a hemp washer being interposed at the point of contact. In the plate, however, a different plan is shown, which is again represented in Fig. 1417. The packing-screws do not pass through the doors, but are kept short; and opposite to each screw a plug is situated in the packing-door, which has to be withdrawn when the packing is to be tightened. In each of these plugs a small recess is turned out, for the reception of a ring of hemp. This recess is better half-round than square.

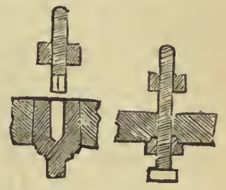
1415.



1416.

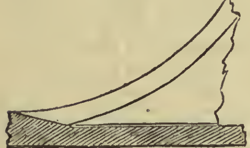


1417.

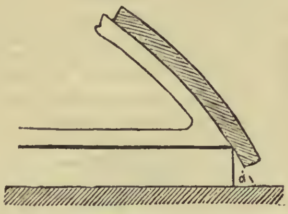


Some packing-blocks are tightened sideways, by screws which are inserted in the sides of the packing ports; but in the plate the block is tightened by its own wedge-shape point, which presses against another wedge-formed piece, cast on the valve-casing, as will be understood by a reference to Fig. 1418. In some cases the end of the packing abuts upon the cylinder face, but generally it overlaps two or three inches in large engines, and a piece, *a*, Fig. 1419, is cast on each side of the cylinder port, in continuation of the circle of the valve, to furnish a surface upon which the packing may press. By this expedient the chance of leakage at the corner of the valve is diminished, and the length of the packing need not be adjusted with such critical exactitude as is necessary by the other arrangement. In some engines the packing of the valve is put in like that of a piston, and is pressed down by means of a junk-ring, but that plan is now little resorted to. Metallic packing has been tried in D valves, but only with very moderate success. The kind that has answered best is a piece of sheet-brass, thinned at the ends, bent to the shape of the valve, and packed behind with hemp.

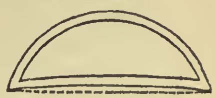
1418.



1419.



1420.



There is a good deal of trouble with every modification of valve faces; but cast-iron working upon cast-iron is perhaps the best combination yet introduced. The usual practice is to pin brass faces on the cylinder, allowing the valve to retain its cast-iron face. Some makers employ brass valves, and others pin brass on the valves, leaving the cylinder with a cast-iron face. Speculum metal and steel have been tried for the cylinder faces, but only with moderate success. In some cases the brass gets into ruts; but the most prevalent affection is a degradation of the iron, owing to the action of the steam, and the face assuming a granular appearance, something like loaf sugar. This action shows itself only at particular spots, and chiefly about the angles of the port, or valve face. At first the action is slow; but, once the steam has worked a passage for itself, the cutting away becomes very rapid, and in a short time it will be impossible to prevent the engine from heating when stopped, owing to the leakage of steam through the valve into the condenser. However truly the D valve may be formed at first, the face will become slightly hollow by the application of heat, as the circular will expand more than the straight part, and the packing resists the enlargement of the circle. The cross-section will therefore assume something of the form shown in Fig. 1420, where the dotted line represents the original position of the face; and on examining a valve newly put in action, it will generally be found that it presses hardest on the tails. The face therefore should be made slightly rounded in the manufacture; and if the engine is a large one, the cylinder must not be faced when lying on its back, unless it has been wedged up to the form it assumes when standing on end, else the partial collapse of the cylinder will

cause the face to become untrue. Copper steam-pipes seem to have some galvanic action on valve faces, and malleable iron pipes have sometimes been substituted; but they are speedily worn out by oxydation, and the scales of rust which are carried on by the steam, scratch the valves and cylinders, so that the use of copper pipes is the least evil. The valve-rod in that part opposite to the steam-port is often much wasted by the steam; it therefore appears expedient to surround it by a copper pipe where an injurious action is to be apprehended. The valve-casing shown in the plates is made close at the bottom, the exhaustion being accomplished by the upper eduction-pipe. In cases in which exhaustion is performed from below, it is expedient to cast two projections on the sole-plate, to prevent the valve from falling down inconveniently far when the valve links are taken off. There is no expansion joint introduced in the valve-casing of these engines, which is a serious defect, as the steam gains admission to the valve-casing before it can enter the cylinder, and the joints are damaged, and in some cases the cylinder is cracked, by the inequality of expansion of the cylinder and valve-casing.

In facing a valve recourse is had to the use of a face plate, to ensure the accuracy of the work. To ascertain whether the face plate bears equally, smear it over with a little red ochre and oil, and move the face plate slightly, which will fix the color upon the prominent points. This operation is to be repeated frequently, and as the work advances, the quantity of coloring matter is to be diminished, until finally it is spread over the face plate in a thin film, which only dims the brightness of the plate. The surface at this stage must be rubbed firmly together to make the points of contact visible, and the higher points will become slightly clouded, while the other parts are left more or less in shade. If too small a quantity of coloring matter be used at first, it will be difficult to form a just conception of the general state of the surface, as the prominent points will alone be indicated, whereas the use of a large quantity of coloring matter in the latter stages would destroy the delicacy of the test the face plate affords. The scraping tool should be of the best steel, and should be carefully sharpened at short intervals on a Turkey stone, so as to maintain a fine edge. A flat file bent, and sharpened at the end, makes an eligible scraper for the first stages; and a three-cornered file, sharpened at all the corners, is the best instrument for finishing the operation. The number of bearing points desirable on the surface of the work depends on the use to which it is to be applied, but in any case the bearing points should be distributed equally over the surface. Great care must be taken in fitting valve faces that the valve be not made conical: unless the back be exactly parallel with the face, it will be impossible to keep the packing from being rapidly cut away. When the valve is laid upon the face-plate, the back must be made quite fair along the whole length, by draw-filing, according to the indications of a straight edge; and the distance from the face to the extreme height of the back must be made identical at each extremity. Should a hole occur either in the valve, in the cylinder, or any other part where the surface requires to be smooth, it may be plugged up with a piece of cast-iron as nearly as possible of the same texture. Bore out the faulty part, and afterwards widen the hole with an eccentric drill, so that it will be of the least diameter at the mouth. The hole may go more than half through the iron: fit then a plug of cast-iron roughly by filing, and hammer it into the hole, whereby the plug will become riveted in, and its surface may then be filed smooth. Square pieces may be let in after the same fashion, the hole being made dovetailed, and the pieces thus fitted will never come out.

Brass faces are put upon valves or cylinders by means of small brass screws, tapped into the iron with conical necks for the retention of the brass: they are screwed in by means of a square head, which, when the screw is in its place, is cut off and filed smooth. In some cases the face is made of extra thickness, and a rim not so thick runs round it, forming a step or recess for the reception of brass rivets, the heads of which are clear of the face.

Air-pump.—The air-pump is attached to the sole-plate by a rust faucet joint, which is preferable to a rust flange joint, as the salt water eats away the heads of the bolts, unless they are copper; and if they are copper, they waste the iron. The oil and grease which fall from the crank-pin upon the sole-plate, deoxidize the rust of a flange joint, whereas with a faucet joint, suitably made, they cannot remain in the same intimate contact. Short steel keys should be driven into the faucet in several places before the joint is made, but they should not rise to the top of the faucet so as to divide the joint into segments.

The air-pump bucket is made with a junk-ring, whereby the packing of the bucket may be easily screwed down. The valve is of the spindle or pot-lid kind. The foot and delivery are of the flap or hanging kind. These valves all make a considerable noise in working, and are objectionable in many ways. Valves of the same construction as those known as Harvey and West's, which are similar to those shown in Fig. 1360, have been employed with advantage by Messrs. Rennie; and valves on Belidor's construction, which is in effect that of a throttle-valve hung off the centre, were some years ago proposed by us for the delivery and foot-valves. Some delivery-valve seats are bolted into the mouth of the air-pump, apparently in the conviction that the pump-bucket never requires to be looked at. If delivery-valves be put in the mouth of the air-pump at all, the best mode of fixing them appears to be that adopted by Messrs. Maudslay. The top of the pump-barrel is made quite fair across, and upon this flat surface a plate containing the delivery-valve is set, there being a small ledge all round to keep it steady. Between the bottom of the stuffing-box of the pump-cover and the eye of the valve-seat, a short pipe extends, encircling the pump-rod, its lower end checked into the eye of the valve-seat, and its upper end widening out to form the bottom of the stuffing-box of the pump-cover. Upon the top of this pipe some screws press, which are accessible from the top of the stuffing-box gland, and the packing also aids in keeping down the pipe, the function of which is to retain the valve-seat in its place. When the pump-bucket has to be examined, the valve-seat may be slung with the cover so as to come up with the same purchase. For the bucket-valves Messrs. Maudslay employ two or more concentric ring-valves, with a small lift. These valves have given a good deal of trouble, in consequence of the frequent fracture of the bolts which guide and confine the rings; but their principle appears superior to that of any of the other air-pump valves at present in common use, with the exception of the equilibrated-valve, in which it is preferable that the face should fall in a groove filled with end-wood. It would not be difficult to make this groove so that the water would have to be forced out of it during

the descent of the valve, whereby the shock would be still further diminished. It would be preferable, however, if all these valves could be discarded in favor of a slide-valve, which might be applied to the air-pump with much advantage.

The air-pump bucket and valves are all of brass, and the chamber of the pump is lined with copper. It is now a common practice to make the chamber of the air-pump wholly of brass, whereby a single boring suffices. When a copper lining is used, the pump is first bored out, and a bent sheet of copper is introduced, which is made accurately to fill the place, by hammering the copper on the inside. Muntz's metal is sometimes used instead of copper, and Muntz's metal air-pump rods are now as generally used as copper rods or iron rods covered with brass. Iron rods covered with brass are not to be commended; they generally are wasted away where the bottom cone fits into the bucket-eye, and if the casing be at all porous, the water will sometimes insinuate itself between the casing and the rod, and eat away the iron. If iron rods covered with brass be used, the brass casing should come some distance into the bucket-eye; the cutter should be of brass, and a brass washer should cover the under side of the eye, so as to defend the end of the rod from the salt water. Rods of Muntz's metal are, probably, on the whole to be preferred; and it is a good practice to put a nut on the top of the rod to secure it more firmly in the cross-head eye. The part which fits into the cross-head eye should have more taper when made of copper or brass than when made of iron; as if the taper be small, the rod may get staved into the eye, whereby it will be so firmly fixed as to make its detachment a difficult operation. Metallic packing has in some instances been employed in air-pump buckets, but its success has not been such as to lead to its further adoption.

Sole-plate and condenser.—Every marine engine, of the side-lever kind, should be constructed with a sole-plate; and we think it the best way that the condenser be cast upon the sole-plate. Engines unfurnished with sole-plates, and with joints between the valve-casing and condenser below the level of the keelsons, are extremely objectionable. Those joints, either from the working of the ship—the movement of the cylinder or condenser—the deoxidizing effect of the oil spilt about the machinery—or the combination of all these causes—will be sure, sooner or later, to become leaky; and it is almost impossible to remake or effectually stanch them. Messrs. Maudslay and Co., in their West India mail packet engines, bolted the condenser to the *under*-side of the sole-plate; by which expedient the rust-joints are preserved, in a great measure, from the action of the grease, and from any strain or vibration consequent upon the yielding of the condenser or cylinder. Messrs. Miller and Co. adopted the same arrangement of condenser, but *cast* the condenser upon the sole-plate.

There are very few of the engines made in Scotland in which the condenser is not cast upon the sole-plate; and in almost all of them the greater part of the condenser is situated above the sole-plate, and the main-centre passes through it. The height of the condenser, in this arrangement, has the advantage of enabling the air-pump to drain it of water very effectually; but the same object is accomplishable by the use of a very large eduction-pipe immediately behind the valve-casing into which the injection water is admitted, and which thus becomes, in effect, a tall condenser. This latter is the arrangement of Messrs. Maudslay and Messrs. Miller. It has the advantage of leaving the space usually occupied above the sole-plate by the condenser, free and unperplexed by any species of machinery except the main-centre, which is supported by pillow-blocks resting or cast on the sole-plate.

The practice of passing the main-centre through the condenser, either with or without a pipe, is objectionable. A pipe is calculated to make the sides of the condenser crack by unequal contraction, and the absence of a pipe endangers a leakage of air round the main-centre joint. The keys employed to fix the main-centre will sometimes occasion trouble, from becoming loose; and, in some instances, we have known a main-centre boss to be split, from the keys being driven too hard. In all cases the thickness of metal requisite in the condenser sides for resisting the strain of the main-centre, will make the sides more liable to crack, in consequence of being suddenly cooled. Upon the whole, the practice of securing the main-centres by plummer-blocks appears greatly preferable: when the main-centre is made to pass through the condenser, the hole should be bored out, and the main-centre ground in with a little taper. It is the usual practice in engines which have the main-centre passing through the condenser, to set the hot well on the top of the condenser, and this is the arrangement in the engines of which we have given the details. A part of the hot well is divided off, to serve as an eduction-passage for the conveyance of the steam from the superior part of the valve-casing. By this arrangement there is no danger of water running from the condenser back into the cylinder. Projections are cast in the foot-valve passage for the reception of the foot-valve seat, by means of which it is keyed into its place; and similar projections are cast in the mouth of the air-pump for the reception of the delivery-valve.

There does not appear to be any man-hole door to the condenser in this engine, which is a defect. It would have been easy to make a man-hole in the curved nozzle leading from the air-pump to the hot well: a door in that situation would have been easy of access from the hot well man-hole, and it would have always been covered with water when the engine was at work, so that a leakage of air could not have taken place. The injection nose-pipe runs across the condenser, near the mouth of the eduction-pipe. A cock, by which water may be injected from the bilge, should the vessel spring a leak, is universally employed in marine engines, and is shown in the sectional drawing of the engines, dotted in. This cock should never be furnished with a rose within the condenser, and should never be joined on to the injection-pipe proceeding from the sea. We have known various cases in which a vessel has been nearly lost from the internal roses of the bilge injection becoming choked up with refuse drawn out of the bilge, and which, but for those roses, would have passed into the condenser and been delivered by the air-pump without creating any obstruction.

Framing.—Cast-iron framing is now given up in marine engines, and malleable iron framing alone is employed. It is a bad plan to attach the diagonal stay to the hot well, as is sometimes done, as the working of the stay breaks the hot-well joint. It is a bad plan, too, to attach the framing to the sides of the ship, as the working of the ship in a sea will strain and may break it. In iron steamers a plan now prevails of running the deep beams before and abaft the crank-hatch (which are also made of iron)

through the ship's side, joining the extremities of those beams by curved cross-beams, on which the shaft plummer blocks are made to rest. The paddle-wheel, by this plan, is overhung, and the whole of the arms radiate from a triple centre. A very substantial framing may be made by adopting this arrangement, and it is one which is applicable in the case of direct-action engines as well as in those on the side-lever plan. The brasses of the paddle-shaft plummer-blocks should not be made with fitting strips on the backs, but the whole of their exterior should be planed, and the interior of the plummer-blocks should also be planed for their reception. Brasses fitted with fitting strips soon wear slack sideways. Octagonal bottom brasses are not so good as those which are square, as they cannot be lined up so conveniently if the shaft gets out of truth. Square-bottom brasses, with flanges, as shown in Fig. 1421, we have found preferable to any other variety.

1421.

Side-lever.—The drawing we have given of the side-lever will sufficiently explain its general form and dimensions. In some of the more recent side-lever engines, the side-levers are made of malleable iron, each lever being composed of two plates, set on edge, the length of the bearings apart from each other. The studs in the side-lever should be steeled, and should be of larger dimensions than is necessary for strength; as if they wear oval, they are likely to burst the side-rod or cross-tail straps, when the brasses are tightened up. Unless the main-centre journals be made spheroidal, there should always be large collars on the main-centre, against which the side-levers may press, so as to prevent lateral play; and the washers on the main-centre ends should be capable of being tightened up against the brasses of the side-lever eye. Without this precaution, the engines will jerk most disagreeably sideways in a sea-way when the brasses come to be at all worn.

Cross-heads and tails, side and connecting-rods.—The parallel motion, it will be remarked in the drawings of details, is attached to the cross-head; but parallel motions are now falling into disfavor, and guides are taking their place. The side-rod eye is fitted with a conical bush, with a spiral cut in it, so that it may be tightened upon the cross-head journal by means of a washer drawn in by a screw. In some cases the side-rod eye is fitted with an octagonal brass, tightened by a cutter beneath the under portion; and in other cases the brass is round, and the upper portion is pressed down by means of a screw, which is made hollow, and serves also as an oil-cup. The upper piece is such as would require to be cut out of the brass, in order to permit the journal to come out without being shifted on end; and the sliding joints of the bush are rebated, to prevent end-play. In the manufacture of brasses of this kind the pieces are first fitted and soldered together; they are then bored and turned; and finally the soldering is loosened by the application of heat. The cross-tail butts are generally ground on to their places, and the end of the cross-tail riveted over on them, a round steel pin being afterwards introduced, half into the cross-tail and half into the butt. In some cases, however, they are put on hot, as practised in the case of cranks; and in the specimen before us a washer is substituted for the riveting of the end. In all cases in which an eye is put on hot against a collar, the eye should be recessed for the reception of a small portion of the collar, as the eye in contracting sideways will leave a space between the collar and the eye, which, by this means, will not be discernible. The connecting-rod is made with a strap to embrace the crank-pin, as is the usual practice. Connecting-rods made in this way should always have a malleable iron cap above the upper brass, instead of having the cap and upper brass made in a piece. If the crank-pin heats, the brass cap will probably be cracked, and cases might be mentioned in which vessels have been nearly lost from such an occurrence.

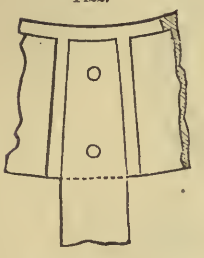
Cranks, eccentrics, shafts, and paddles.—The cranks and shafts of marine engines are now always made of wrought-iron. The crank is shrunk on the shaft hot, and a strong square key is then driven in at the part nearest the web, so as to obviate the weakening of the eye. The crank-pin is fixed in the intermediate crank, and is loose in the eye of the paddle-crank, which is fitted with a bush, upon which the rounded end of the crank-pin bears. The end of the crank-pin, fitting into the eye of the intermediate crank, is made conical, and is drawn into its place by a cutter passing through both pin and eye. The rounded end of the pin enables the paddle-shaft to fall at the outer end, as it always does, without breaking the pin. In some cases a drag-link is used instead of the rounded pin, but drag-links are not now much in fashion. A very good method of fixing the crank-pin into the eye consists in the application of a strong washer over the crank-eye, with a hole in the centre, through which a stout bolt passes tapped into the pin. The washer is indented a little into the crank-eye, so as to obviate any tendency to move laterally. This plan is unattended with any more trouble than if the pin were riveted in, and it admits of the pin being taken out by merely unscrewing the bolt of the washer. The end of the pin inserted in the loose eye is of course made spheroidal, so as to permit the outer end of the shaft to drop a little, without breaking the pin. The pin is steeled on both sides of this spheroidal part, and bears against two dovetailed steel plates. The plate situate on the *backing* side was, in the case of the Don Juan, tightened by means of a screw passing through the crank-eye. The web of the crank was made thicker and narrower than usual, the intention of the makers being that the web should be capable of resisting the twist occasioned by the overhang of the crank-pin more effectually than is done in the case of cranks whose shape is regulated by the supposition that the crank-pin does not overhang at all. There is more plausibility than soundness in this reasoning; the fact being, that the strength given for the single purpose of overcoming the leverage, is more than sufficient to withstand the twist. The crank-pin must be fitted very accurately into the crank-eye, else it will be very liable to be broken. The crank-pin should always be larger in diameter than is necessary for strength, for the purpose of keeping the journal from heating. The dimensions given in our tables will be found to answer very well, and they are slightly in excess of the common proportions.

We may here set down a few remarks about paddle-wheels, which cannot well be severed from the subject of the engine. The best plan of making the centres is with square eyes, and each centre should be secured in its place by means of eight *thick* keys. The shaft should be burred up against the heads of these keys with a chisel, so as to prevent the keys from coming back of their own accord. If the keys are wanted to be driven back this burr must be cut off, and the keys, if made thick and of the right

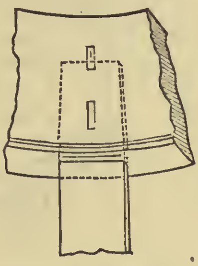
taper, may then be started without difficulty. The shaft must of course be forged with square projections on it, so as to be suitable for the application of centres with square eyes. Messrs. Maudslay & Co. bore out their paddle-centres and turn a seat for them on the shaft, afterwards fixing them on the shaft with a single key. The plan is objectionable for two reasons—it is insecure when new, and when old is irremoveable. One of the West India mail vessels, by Messrs. Maudslay, was almost disabled from this cause on the first voyage, the key on the shaft having slackened, and the centre having consequently turned round; and in some of the older vessels by the same makers, lately under repair at Woolwich, the centres had to be broken off, for they could not be got off in any other way. With this plan of centre we have often known the centres to shift: in one case the wheel on the weather side was forced against the side of the ship, and the floats, in their revolution, cut deeply into the outside planking. The plan of making round bosses on the shaft, and fixing the centres with four keys, as shown in our plates of details, is also objectionable on the ground of insecurity.

The general practice among the London engineers, is to fix the paddle-arms at the centre to a plate by means of bolts, Fig. 1422, a projection being placed upon the plates on each side of the arm, to prevent lateral motion. We have found this method to be inferior in durability to that adopted in the Clyde, Fig. 1423, in which each arm is fitted into a socket by means of a cutter, a small hole being left opposite to the end of each arm, whereby the arm may be forced back by a drift. A preferable way would be to form the paddle-centre out of the arms themselves, by widening them at the head until they touch one another, Fig. 1424, and then applying a boiler-plate upon one side, and riveting the arms firmly to it. If this plan be adopted, it will be expedient to swell the tops of the uncovered side at the part nearest the centre, so as to increase the length of bearing for the keys which secure the centre to the shaft. In the manufacture of this centre the heads of the arms would first be forged, then planed on the edges and fitted together on the plate. The holes would then be bored for the rivets, temporary bolts fitted into them, and the key-seats cut and the ends of the arms pared in the slotting-machine. Finally, the arms would be welded on to the heads, and the various parts of the wheel riveted together.

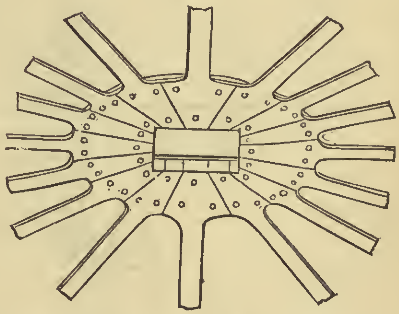
1422.



1423.

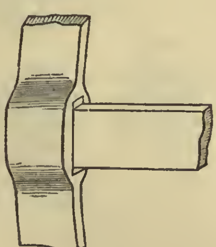


1424.

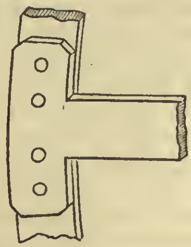


Most of the London engineers join the paddle-arms to the outer ring, by means of bolts, but those bolts, after a time, generally become slack sideways, and a constant working of the parts of the wheel goes on in consequence. Some engineers form the part of the outer ring opposite the arm into a mortise, Fig. 1425, and they wedge the arms tight in the hole by wedges driven in on each side. But the plan is an expensive one, and not satisfactory, as the wedges work loose even though riveted over at the point. The best mode is the plan for the most part practised in the Clyde, Fig. 1426, of making the arm with a long T-head, and riveting the cross-piece to the outer ring with a number of rivets, not of the largest size, which would weaken the outer ring too much. The best way of securing the inner rings to arms is by means of lugs, Fig. 1427, welded on the arms, and to which the rings are riveted.

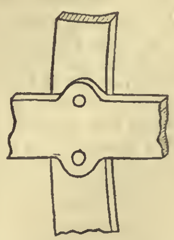
1425.



1426.



1427.

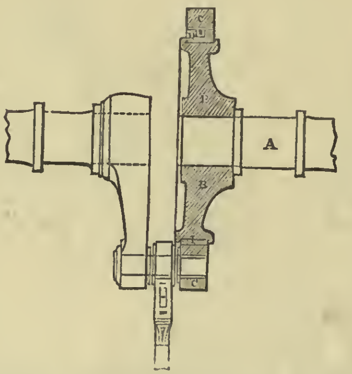


Paddle-floats are usually made either of elm or of pine; if of the former, the common thickness for large sea-going vessels is about 2½ inches; if of the latter, 3 inches. They should have plates on *both* sides, else the paddle-arms will be very liable to cut into the wood, and the iron of the arms will be rapidly wasted. When the floats have been fresh put on, they must be screwed up several times before they come to a bearing. If this be not done, the bolts will be sure to get slack at sea, and all the floats

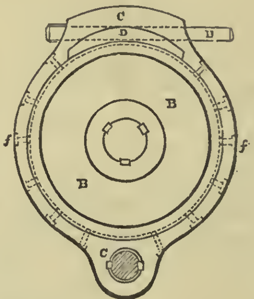
on the weather side may be washed off, as once occurred to the British Queen, on the next voyage after the floats had been removed to allow the vessel to go into dock. It is a good plan to give the threads of the paddle-blocks a nick with a chisel after the nut has been screwed up, which will prevent the nut from turning back. The floats should not be notched out, to allow of their projection beyond the outer ring; as, if the sides of the notch be in contact with the outer ring, the ring is soon eaten away in that part, and the projecting part of the float, being unsupported, is liable to be broken off. It is usual to put a steel plate at each end of the paddle-shaft, tightened with a key, to prevent end-play when the vessel rolls, but the arrangement is precarious and insufficient. Messrs. Maudslay make their paddle-shaft bearings with very large fillets in the corner, with the view of diminishing the evil; and Mr. R. Napier causes the crank-eyes of both paddle and intermediate cranks to bear sideways against the brasses of the plummer-blocks. It would be preferable to make the bearings of the crank-shafts spheroidal, and, indeed, it would be an improvement if most of the bearings about the engine were to be made in the same fashion. The spheroidal form would not only prevent end-play, but would keep the oil from running out at the ends of the bearings. The loose end of the crank-pin should be made not spheroidal, but consisting of a portion of a sphere, and a brass bush might then be fitted into the crank-eye, that would completely encase the ball of the pin, and yet permit the outer end of the paddle-shaft to fall without straining the pin, the bush being at the same time susceptible of a slight end-motion. This arrangement is far preferable to that of making the pin bear upon a single point, as is the common practice. There is an inconvenient amount of wear on the pin, which involves a back-lash in the eye, and the point of contact sometimes heats and screeches, unless the eye be kept well supplied with tallow.

Disengaging paddle-wheels.—Many plans have been contrived for disengaging the paddle-wheels of steamers, so as to enable one paddle to be worked without the other, or both paddles to be thrown out of geer, so as to revolve loosely when the vessel is under sail. The best of these expedients is that represented in Figs. 1428 and 1429, where A is the paddle-shaft; B, a cast-iron disk keyed thereon; C,

1428.



1429.

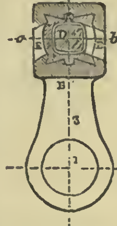


a wrought-iron strap surrounding the disk, lined with brass; D, a brass cushion with a tightening key for producing friction, by bringing the cushion in contact with the disk; F, the brass lining of the wrought-iron strap, excepting that portion occupied by the cushion; *f f f*, screws by which the brass lining is held to the strap. A few blows of a hammer on the key D will connect or disconnect the paddle-shaft, even when the engines are at full speed.

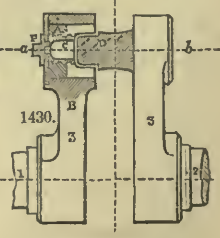
Messrs. Maudslay's method of disconnecting is to shift the shaft on end by suitable geer, until the crank-pin leaves the crank-eye. Messrs. Miller's method is to put a clutch on the shaft, which catches into the paddle-centre—the whole of the three centres being combined into one diverging one, which runs loose on the shaft. A method contrived by Mr. Grantham is represented in Figs. 1430, 1431, and 1432, where A is a moveable bush in the paddle-crank eye; B, the crank; C, a screw for moving in or out the bush; D, crank-pin; E, slot in the crank-eye to permit the pin to pass in the revolution of the crank, except when the pin-bush is moved out to engage it; F, square head of screw C; G, H, the bush engaged with the crank-pin. It is obvious that by screwing the bush out or in, the crank-pin is either engaged with or disengaged from the paddle. In Messrs. Seaward's engines a method of disengaging almost identical with this is sometimes employed.

1431.

1432.



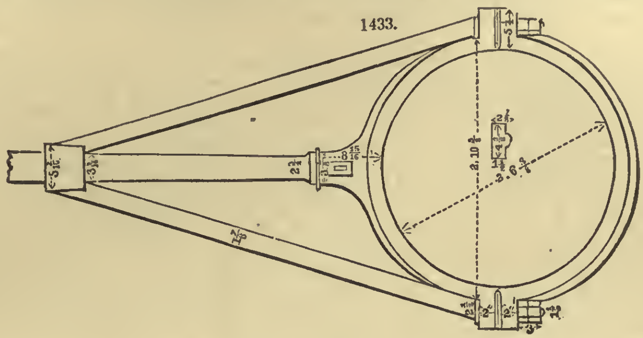
1430.



Eccentrics.—The eccentrics of marine engines are always put on in two pieces; they are almost always loose on the shaft, and are always capable of backing. The manner in which that shown in our plates of details is made, is a common one. The eccentric is loose upon the shaft, and is furnished with a back balance and catches, and the halves are put together with rebated joints, to keep them from separating laterally; and they are prevented from sliding out by round steel

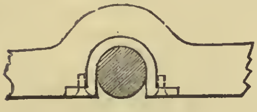
pins, each ground into both halves. Square keys would be preferable to round pins in this arrangement, as the pins tend to wedge the jaws of the eccentric asunder. In some cases the halves of the eccentric are bolted together by means of flanges. The eccentric-rod shown in the plates of details is not a particularly neat one. The eccentric-rod of the Don Juan is represented in Fig. 1433, and that

1433.



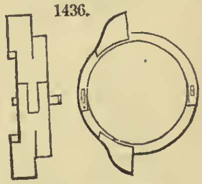
form is now widely adopted. It is expedient to cast an oil-cup on the eccentric-hoop, and where it is practicable, a pan should be placed beneath the eccentric, for the reception of the oil-droppings. The notch of the eccentric-rod, for the reception of the pin of the valve-shaft, is usually steeled, to prevent inconvenient wear; for when the sides of the notch wear, the valve movement is not only disturbed, but it is very difficult to throw the eccentric-rod out of geer. It is found to be preferable, however, to fit this notch with a brass bush, Fig. 1434, for the wear is then less rapid, and it is an easy thing to replace this bush with another when it becomes worn. The eccentric catches shown in the plates are the kind usually employed, but catches of this kind sometimes break off at the first bolt-hole, and it is preferable either to have a bolt in advance of the catch-face, as in Fig. 1435, or to have a hoop encircling the shaft, with the catches welded on it, the hoop itself being fixed by bolts or a key. This hoop may either be put on before the cranks in one piece, or afterwards in two pieces, as shown in Fig. 1436. The

1434.



1435.

1436.



expansion-cam is figured in the plate; it is put on the shaft in two pieces, which are fastened to each other by means of four bolts passing through lugs, and is fixed to the shaft by keys. A roller at one end of a bell-crank, which is connected with the expansion-valve, presses against the cam, so that the motion of the lever will work the valve. The roller is kept against the cam by a weight on a lever attached to the same shaft. If the cam were concentric with the shaft, the lever which presses upon it would remain stationary, and also the expansion-valve; but by the projection upon the cam, the end of the lever receives a reciprocating motion, which is communicated to the valve. The position of this projection determines the point in relation to the stroke at which the valve is opened, and the extent of the projection determines the duration of opening. The time at which the valve should begin to open is the same under almost all circumstances; but the duration of its opening varies with the amount of expansion desired. In order to obtain this variable expansion, there are several projections made upon the cam, each of which gives a different degree or *grade*, as it is usually called, of expansion. These grades begin at the same point on the cam, but are of different lengths, so that they would begin to move the lever at the same time, but would differ in the time of returning it to its original position. The change of expansion is effected by moving the roller on to the desired grade. There are seven different grades in the West India steamers. The expansion-valve is of the kind used in the Cornish engines, and known as the equilibrium valve. Of the valve-shafts and links, parallel-motion rods, and other similar details, it is needless here to speak, as there is nothing of difficulty connected with those parts, and the plates make their arrangement sufficiently intelligible.

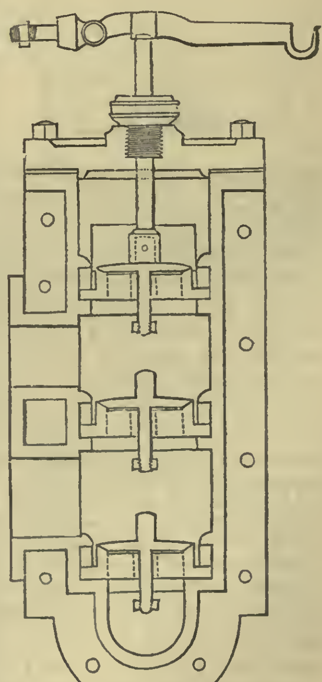
Starting-geer.—The best starting geer is Stephenson's link motion, which will be described in our remarks respecting details of locomotives. This combination obviates the necessity of throwing the engines out of geer at all; and full speed ahead may be changed instantaneously into full speed astern, and without stopping the engines. Messrs. Rennie have introduced this species of starting-geer into the Samson and some other steam vessels with the most satisfactory results; and it appears likely to become general, at least in valves where there is little lap. In our plates of details the valve is moved by means of a lever, and the eccentric-rod is thrown out of geer by means of a pulley on the end of a lever, which, when raised, forces the pulley against the under side of the rod and lifts it out of the notch. The act of raising this pulley depresses another pulley on a lever fixed upon the same shaft, and enables another rod in connection with the starting-handle to fall into geer, the intention being, that when the eccentric-rod is in geer, the starting-handle shall be without motion, as its swinging would be

inconvenient and dangerous if worked by the engine. This plan of preventing the starting-handle and the eccentric-rod from being in geer at the same time has now come into general use. The method adopted by Napier in the Precursor is a very elegant one: it consists in the use of an eccentric-stud for supporting the lever which carries the roller; and the act of moving this lever, so as to enable the eccentric-rod to fall into geer, draws back the pinion of the starting-shaft out of the sector, with which it is engaged. Instead of a lever, the starting-shaft in this case is moved by a wheel similar to a steering wheel of a ship.

Brine-pumps.—Pumps for changing the water in marine engine boilers, so as to prevent the salt water from reaching an inconvenient degree of saturation, were first applied by Messrs. Boulton and Watt to the City of Edinburgh steamer, and their use is now very general. In the engines of the Centaur, represented in the plate of direct-action engines, the brine-pumps are set on each side of the feed-pump, and are wrought with it off the air-pump cross-head. In some cases the feed water is sent into a vessel called a refrigerator, through which the super-salted water proceeding from the boiler to the brine-pump is conducted in a multitude of small pipes,—the intention of the arrangement being to economize heat by communicating the heat of the super-salted water to the feed. But the amount of heat thus saved is exceedingly unimportant, and the refrigerators are not only expensive to construct, but are very liable to be choked up by deposite. They thus become a source of danger, as the engineer is led to confide in an expedient which may deceive him, while he believes it to be in effective operation. The valves of brine-pumps require to be loaded sufficiently to counteract the pressure of the steam, and of the head of water in the boiler. If brine-pumps be used, it appears preferable to use them without the refrigerator; they then become equivalent to a continuous blowing off, but the pipes are less liable to choke, and there is no blowing off while the engines are at rest.

Sea-water contains about 1-33 its weight of salt, and its specific gravity is increased by boiling until it contains 12-33 of salt, which is the point of saturation, and the water will not then hold more salt in solution. As the water is more concentrated, it requires a higher temperature to make it boil. The boiling point of sea-water which has 1-33 of salt, is 213·2°; with 2-33, 214·4°; with 3-33, 215·5; with 4-33, 216·7°; with 5-33, 217·9°; with 6-33, 219°; with 7-33, 220·2°; with 8-33, 221·4°; with 9-33, 222·5°; with 10-33, 223·7°; with 11-33, 224·9°; and saturated water 226°. These are the boiling points in the open air; in a steam boiler, where the pressure of steam is always above the pressure of the atmosphere, the boiling points will be correspondingly higher, but with any uniform pressure of steam in the boiler it is possible to make the thermometer an index of the saltness of the water. If the water be maintained at a concentration of 4-33, or if about one-fourth of the water be withdrawn from the boiler by the brine-pumps that is forced in by the feed-pumps, very little deposite will collect within the boiler. The quantity of fuel wasted by blowing off this quantity of water, cannot, it is clear, be considerable, and there should not be less blown off. Of every 4 cubic feet of water entering the boiler from the hot-well, 3 passes off in steam and 1 in brine. The temperature of the hot-well being 100°, the heat imparted to the water to raise it into steam, may be represented by $1112° \times 3 = 3336$, while the heat contained in the brine is 112°, or rather less, the specific heat of brine being less than that of fresh water, and $3336 \div 112 = 29$, so that about 1-29th of the heat passes out of the super-salted water when large blowing off is practised. A much larger quantity of heat than this goes to waste if there be any material accumulation of scale upon the flues, and engineers will therefore see that there is no economy in penurious blowing off.

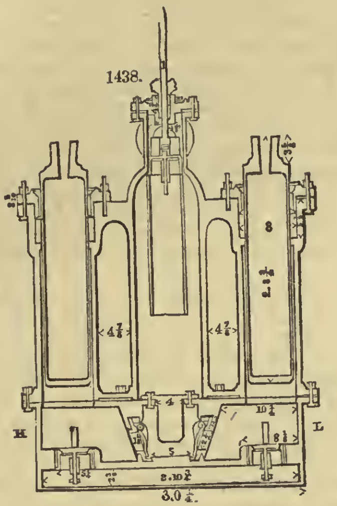
1437.



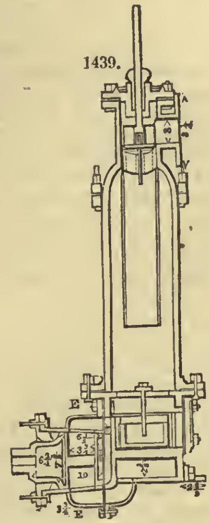
Pumps, cocks, and pipes.—In the plates of details the feed-pump plunger is shown with a screw at the bottom, for the extraction of the core, but it appears preferable to extract the core out of a hole in the top, which may be adapted for the reception of the pump-rod. There should be a considerable clearance between the bottom of the plunger and the bottom of the pump-chamber, as otherwise the bottom of the chamber may be knocked out, should coal-dust or any other foreign substance gain admission, as it probably would do, if there were any injecting from the bilge. Messrs. Maudslay make the feed and bilge pump plungers serve as guides to the air-pump cross-head, the pump-rods being continued upwards and working through eyes in the framing. We do not see any objection to this arrangement, if the stuffing-boxes be made deep: when separate guide-rods are used with eyes in the cross-head, those eyes should be fitted with stuffing-boxes, to diminish the wear, and the guides should be made very strong, for the same reason. The valves of the feed-pump are most conveniently arranged in a chest, which may be attached in any accessible position to the side of the hot-well. An arrangement of this kind is shown in Fig. 1437. Of the two side nozzles, the lower one leads to the pump and the upper one to the boiler. The pipe leading to the pump is a suction-pipe when the plunger ascends, and a forcing-pipe when the plunger descends. The plunger, in ascending, draws the water out of the hot-well through the lowest of the valves, and in descending, forces it through the centre valve into the space above, which communicates with the feed-pipe. Should the

feed-cock be shut, so as to prevent any feed-water from passing through it, the water will raise the topmost valve, which is loaded to pressure considerably above the pressure of the steam, and escape into the hot-well. This arrangement is neater and less expensive than that of having a separate loaded valve on the feed-pipe, with an overflow through the ship's side, as is the more usual practice. Figs. 1438 and 1439

1438.

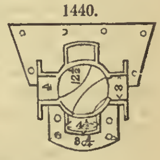


1439.



represent a double-acting deck feed-pump of a very complete and efficient construction. It is of the plunger kind, which is preferable to that which operates by a piston. The air-vessel is furnished with an escape-valve, to prevent the pump from being split should it be put in connection with the engine when the cocks in the pipe leading to the boiler are closed, an accident which not unfrequently happens. Fig. 1440 represents a four-way cock, the application of which enables the pump to draw from the sea, from the boiler, or from the bilge, and the pump can deliver either into the boiler or upon deck. This pump can be worked either by the engine or by hand: it is employed to feed the boilers when the engines are stationary, or to pump the boilers out, after they are blown off as far as can be accomplished by the steam. At other times it is useful for raising the water to wash the decks, to act as a fire-engine in case of fire, and to pump out the ship if she springs a leak.

1440.



In most of the new vessels fitted with tubular boilers, small engines have been introduced, to pump water into the boiler when the vessel stops under steam. Most of these engines are furnished with a crank and fly-wheel, but that introduced by Messrs. Penn has no fly-wheel, and is a very compact and elegant arrangement. The pump-piston and the steam-piston are at different ends of the same rod, and, instead of the ordinary pump-valves, a slide-valve is introduced, which is situated at the opposite end of the steam slide-rod. The slide-valves are pipe-valves, and are moved by means of a tappet on the piston-rod. On another part of the same plate some views are given of a self-acting feed apparatus, which consists of a small chest, placed upon the front of the boiler at the level of the water-line, with ports, closed by a sliding-plate, communicating with the water in the boiler and the steam above it. When these ports are opened the water rises to the same height in the chest as in the boiler, and the ports are opened and shut by the small engine at every stroke of the pump. While the pump is making its stroke the ports leading from the chest to the boiler are closed, and if the chest be chiefly filled with steam, it will be compressed by the entering water, and the chest will receive a charge of water, which, on the ports being opened, will flow into the boiler. But if there be but little steam in the chest when the pump is making its stroke, or the chest be filled with water from the rise of the water-level, the water discharged by the pump cannot gain admission, and it must therefore escape overboard through the loaded valve. Thus, as the water-level rises, the chest takes less water from the pump, and it takes more when the level falls, the effect of which in practice is to maintain a uniform water-level in the boiler, however great the variations in the demand for steam. In some steam vessels floats have been introduced to regulate the feed, but their action cannot be depended on in agitated water, if applied after the common fashion. Floats would probably answer if placed in a cylinder which communicated with the water in the boiler by means of small holes; and a disk of metal might be attached to the end of a rod extending beneath the water-level, so as to resist irregular movements from the motion of the ship, which would otherwise prevent the satisfactory action of the apparatus.

This disk would be placed within the cylinder, and a short distance above it a fixed diaphragm might extend across the cylinder, between which and the moveable disk or piston on the rod the water would be compressed, in the event of any sudden disposition of the float to rise, such as might be created by the sudden motions of the ship; whereas by the slow and gradual subsidence of the water-level from evaporation, the water in the cylinder would be able to subside by gradually passing through the small holes in the cylinder and disk. One objection to this plan is, that the small holes would be liable to be

closed up by deposite; and the preferable arrangement, probably, would be to place the float within the boiler, guided, but without any cylinder, and to apply a small oil cylinder, such as is used for the cataract of some pumping engines, to the end of the float-rod where it protrudes through the top of the boiler. Such an arrangement would enable the float to resist suddenly acting forces, while any force that was gradual and steadily operative would still produce its due effect.

The admission of the feed-water into the boiler is sometimes regulated by cocks, and sometimes by spindle-valves, raised and lowered by a screw. Cocks are less liable to accident or derangement than screw-valves, and in modern steam vessels are generally employed. The feed-water is usually conducted from the feed-cock to a point near the bottom of the boiler, by means of an internal pipe,—the object of the arrangement being to prevent the rising steam from being condensed by the entering water. By being introduced near the bottom of the boiler, it comes into contact in the first place with the bottoms of the furnaces and flues, and extracts heat from them, which could not be extracted by water of a higher temperature, whereby a saving of fuel is accomplished. In some cases the feed-water is introduced into a casing around the chimney, from whence it descends into the boiler. This plan appears to be an expedient one when the boiler is short of heating surface, and more than a usual quantity of heat ascends the chimney; but in well-proportioned boilers a water casing round the chimney is superfluous. When a water casing is used, the boiler is usually fed by a head of water, the feed-water being forced up into a small tank, from whence it descends into the boiler by the force of gravity, while the surplus runs to waste, as in the feeding apparatus of land engines, represented in Fig. 1439.

Blow-off cocks are generally placed some distance from the boiler, but they should always be placed quite close to it, as there are no means of shutting off the water from the pipe between the blow-off cock and the boiler, should fracture or leakage there arise. Every boiler must be furnished with a blow-off cock of its own, independently of the main blow-off cock on the ship's sides, so that the boilers may be blown off separately, and may be shut off from one another. The preferable arrangement appears to be, to cast upon each blow-off cock a bend for attaching the cock to the bottom of the boiler, and the plug should stand about an inch in advance of the front of the boiler, so that it may be removed or reground with facility. The floor-plate covering the blow-off cock should have a cooming, a few inches high, cast round a hole of sufficient diameter to admit a box-key to turn the plug, and to each plug a box-key should be fitted with a collar, at the level of the top of the cooming, of sufficient diameter to cover the hole and thickness of metal around it, and with the top of the key-spindle supported by an eye attached to the boiler. These box-keys would not be shifted from one plug to another, as at present, but each would remain in its place, and the engineer would only have to turn them when he wanted to blow off the boilers. The present method of using the blow-off cocks is very inconvenient. A small plate has to be removed to enable the box-key to be applied; coal sometimes is lying upon the plate, which has to be removed, and coal-dust gets into the bilge in these continual removals, which chokes the roses of the bilge-pumps. In dark nights and rough weather, the engineer requires to feel the nick in the top of the plug, which is often filled with coal-dust and grease, before he can assure himself whether the cock is open or shut, and the operation of turning the cocks is more difficult when the spindle of the key is without support. These evils may be remedied by the arrangement suggested. The spindle will require to be made with a hole or eye to admit a handle wherewith to turn it round, and it would be an easy thing to make the stud supporting the top of the spindle of such a form that the handle for turning the spindle could not be withdrawn when the cock was open. The cock, therefore, could not be left open without the handle being left in its place, where it would stand out from the boiler, incommode the firemen, and duly notify the neglect.

The general arrangement of the blow-off pipes is to put a main blow-off pipe beneath the floor-plates across the ship at the end of the engines, and into this pipe lead a separate pipe, furnished with a cock, from each boiler. The main blow-off cock, where it penetrates the ship's side, is furnished with a cock; and in modern steam vessels Kingston's valves are also used, which consist of a spindle or plate-valve fitted to the exterior of the ship, so that if the internal pipe or cock breaks, the external valve will still be operative. Some expedient of this kind is almost necessary, as the blow-off cocks require occasional regrinding, and the sea cocks cannot be reground without putting the vessel into dock, except by the use of Mr. Kingston's valves or some equivalent expedient. When old vessels are getting new sea cocks applied, it may answer to make the old cocks serve the purpose of Kingston's valves, the new cocks being applied between the old cocks and the blow-off pipes.

All the cocks about an engine should be provided with bottoms and stuffing-boxes, and reliance should never be placed upon a single bolt passing through a bottom washer for keeping the plug in, in the case of any cock communicating with the boiler, for a great pressure is thrown upon that bolt if the pressure of the steam be high and the plug be made with much taper; and should the bolt break or the threads strip, the plug will fly out, and persons standing near may be scalded to death,—an accident which has sometimes happened. In large cocks it appears the preferable plan to cast the bottoms in; and the metal of which all the cocks about a marine engine are made should be of the same quality as that used in the composition of the brasses, and should be without lead or other deteriorating material. In some cases the bottoms of cocks are burnt in with hard solder, but this method cannot be depended upon, as the solder is softened and wasted away by the hot salt-water, and in time the bottom leaks or is forced out. The stuffing-boxes of cocks should be made of adequate depth, and the gland should be secured by means of four strong copper bolts. The taper of blow-off cocks is an important element in their construction; as if the taper be too great, the plugs will have a continual tendency to rise, which, if the packing be slack, will enable grit to get between the faces; while, if the taper be too little, the plug will be liable to jam, and a few times grinding will sink it so far through the shell, that the water-ways will no longer correspond. One-eighth of an inch deviation from the perpendicular for every inch in height is a common angle for the side of the cock, which corresponds with one quarter of an inch difference of diameter in an inch of height; but one-third of an inch difference of diameter for

every inch of height, is a preferable proportion. The bottom of the plug must be always kept a small distance above the bottom of the shell, and an adequate surface must be left above and below the water-way, to prevent leakage. Cocks formed according to these directions will be found to operate satisfactorily in practice.

Gage-cocks are rarely made with stuffing-boxes, and are for the most part adorned with stalactites of salt after a short period of service, in consequence of leakage. The water discharged from them, too, disfigures the front of the boiler, and adds to the corrosion in the ash-pits. It would be preferable to combine the gage cocks appertaining to each boiler into a single upright tube, connected suitably with the boiler, and the water flowing from them could be directed downwards into a funnel tube communicating with the bilge. The gage-cocks and also the glass tube-cocks should be furnished with stuffing-boxes, and with bottoms, unless the water enters through the bottom of the plug. The glass gage-tubes should always be fitted with a cock at each neck, communicating with the boiler, so that both the water and steam may be shut off if the tube breaks. The gage-cocks frequently have pipes running up within the boiler, to the end that a high-water level may be made consistent with an easily accessible position of the gage-cocks themselves. With the glass tubes, however, this species of arrangement is not possible, and the glass tubes must always be placed in the position of the water level, whether it be high or low.

The sea injection-cocks are usually made in the same fashion as the sea blow-off cocks, and of about the same size. The injection water is generally admitted to the condenser by means of a slide-valve, but a cock is more easily opened, and has not any disposition to shut of its own accord. The sea injection-pipes should be put through the ship's side in advance of the paddles, so that the water drawn in may not be injuriously charged with air. In some cases the suction-pipe of the deck-pump leads into the injection-pipe; but it is preferable to put a pipe through the ship's side for the exclusive use of the deck-pump, as is the general practice. The waste-water pipe, passing from the hot-well through the vessel's side, is provided with a stop-valve, called the discharge-valve, which is usually made of the spindle kind, so as to open when the water coming from the air-pump presses against it. In some cases this valve is a sluice-valve, but the hot-well is then almost sure to be split if the engine be set on without the valve having been opened. The opening of the waste-water pipe should always be above the load water line, as it will otherwise be difficult to prevent leakage through the engine into the ship, when the vessel is lying in harbor.

Boilers are now generally supplied with stop-valves, whereby one boiler may be thrown out of use without impairing the efficacy of the remainder. These stop-valves are usually spindle valves of large size, and they are for the most part set in a pipe which runs across the steam-chests connecting the several boilers together. The spindles of these valves should project through stuffing-boxes in the covers of the valve-chests, and they should be balanced by a weighted lever and kept in continual action by the steam. If the valves be lifted up and be suffered to remain up, as is the usual practice, they will become fixed by corrosion in that position, and it will be impossible after some time to shut them on any emergency. These valves should always be easily accessible from the engine-room, and it ought not to be necessary for the coal boxes to be empty to gain access to them. The safety-valves should not be set on the common pipe connecting the boilers, but each boiler should have a safety-valve of its own set direct upon the steam-chest, for if the stop-valve should jam, and the safety-valve be exterior to it, the safety-valve cannot contribute any thing to save the boiler from explosion. Each boiler also should have a distinct steam-gage and a distinct atmospheric valve, if atmospheric valves be applied at all, but they scarcely appear to be necessary in the case of tubular boilers, which are capable of withstanding the atmospheric pressure with impunity.

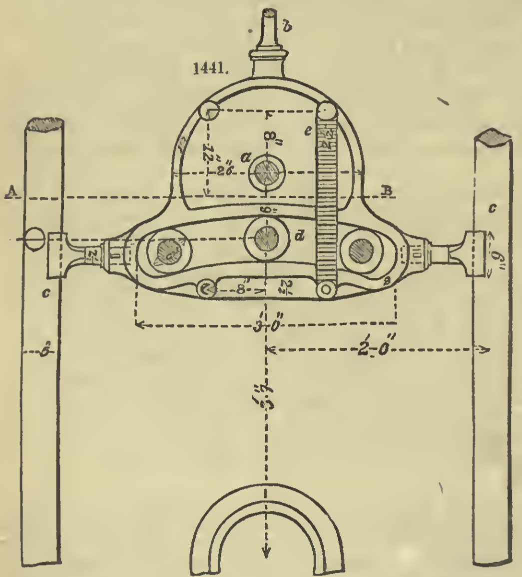
The pipes of marine engines should always be made of copper. Cast-iron blow-off pipes have in some cases been employed, but they are liable to fracture, and are dangerous. Every pipe passing through the ship's sides, and every pipe fixed at both ends and liable to be heated and cooled, should be furnished with a faucet or expansion joint, and in the case of cast-iron pipes, the part of the pipe fitting into the faucet should be turned. In the distribution of the faucets of the pipes exposed to pressure, care must be taken that they be so placed that the parts of the pipe cannot be forced asunder by the strain, as serious accidents have occurred from the neglect of this precaution. A faucet is usually placed where the main steam-pipe joins the branch steam-pipes proceeding to the cylinders, and if those branch steam-pipes are attached to the cylinders or valve-casings by means of faucets, the whole of the branch steam-pipes may swivel round on these faucets and leave the main steam-pipe, which will then discharge its full volume of steam into the engine room, an accident which could hardly fail to be attended with the most disastrous consequences.

Where the pipes pierce the ship's side, they should be made tight, as follows:—The hole being cut, a short piece of lead pipe with a broad flange at one end should be fitted into it, the place having been previously smeared with white-lead, and the pipe should then be beaten on the inside until it comes into close contact all round with the wood. A loose flange should then be slipped over the projecting end of the lead pipe, to which it should be soldered, and the flanges should both be nailed to the timber with scupper nails, white-lead having been previously spread underneath. This method of procedure prevents the possibility of leakage down through the timbers, and all therefore that has to be guarded against after this precaution, is to prevent leakage into the ship. To accomplish this object, let the pipe which it is desired to attach be put through the leaden hawse, and let the space between the pipe and the lead be packed with gasket and white-lead. The pipe must have a flange upon it to close the hole in the ship's side; the packing must then be driven in from the outside and be kept down by means of a gland secured with bolts passing through the ship's side. If the pipe is below the water-line, the gland must be of brass, but for the waste-water pipe a cast-iron gland will answer. In the case of iron vessels, it appears to be the best practice to attach a short iron nozzle, projecting inwards, to the skin, for the attachment of every pipe below the water-line, as the copper or brass would waste the iron of the skin if the attachment were made in the usual way.

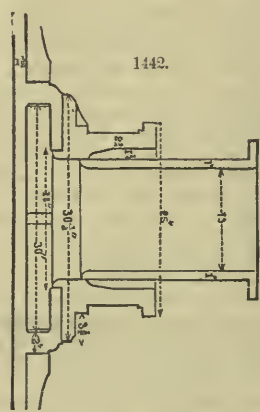
Parts of oscillating engines.—The most important parts of oscillating engines are the piston, the piston-rod stuffing-box, the trunnions, and the attachment for the valve. The two former parts we have already described; we shall here give the chief details of the two latter.

Fig. 1441 represents the valve attachment to the steam vessel the Trident, constructed by Messrs. Boulton and Watt, cylinder 70¾ inches diameter, and 5 feet stroke, and reckoned at 350-horse power. The eccentric rod is attached to the stud *a*, which is fixed to the centre of a plate forming part of a frame which is guided vertically by means of the guide-rod *b*, and by the columns of the engine at *c c*. *d* is the end of the valve lever which is moved up and down by the frame, whatever position in the arc the end of the lever may occupy in consequence of the oscillation of the cylinder. *e* is a rack whereby the frame may be moved up or down by means of a shaft at A B, when the eccentric rod is not in geer, and at the end of the shaft a wheel is situated for starting the engine. The curved groove in which the end of the valve lever moves is part of a circle, but it is not swept from the centre of the trunnion when the valve is at half-stroke, but with a radius equal to the distance of the centre of the valve-shaft from the centre of the trunnion, when the cylinder is perpendicular. Messrs. Penn do not form the curve in this way, but sweep it from the centre of the trunnion when the valve is at half-stroke; and although the same motion of the valve is not thus obtained as when there is no oscillation, the difference is very slight, and is moreover considered to be a better motion than if no disturbance had taken place. It appears to us that the use of a curve might be dispensed with altogether by observing a suitable adjustment of the eccentric; the effect would probably be to increase slightly the side pressure on the piston rod, but the increase would be altogether inappreciable in the case of equilibrated valves which may be wrought with an inconsiderable exercise of force.

1441.



1442.



Scale.—¼ inch=1 foot.

Fig. 1442 represents one of the trunnions of the Trident, which, instead of being cast upon the cylinder, as is the usual practice, are bolted on with twelve 1¼-inch bolts, and are strengthened by twelve brackets, 1 inch thick, cast on the flanges of attachment. There is a projecting ring, it will be observed, left upon the part which is to be bolted on, which is accurately fitted into the hole in the belt in order to obviate slackness sideways. A rib 1½ inch thick runs back from the hole on each side in the middle of the belt, to tie the belt more effectually to the cylinder, and above and below the belt a feather runs vertically 1½ inch thick, and tapering in depth from the belt till it runs off to nothing on the cylinder side.

The bearing part of the trunnion is 22 inches diameter, 7 inches long, and the metal is 2¼ inches thick; the steam-pipe entering the trunnion is 1 inch thick, and the packing space between the pipe and trunnion 1¼ inch wide. The gland for compressing the packing is usually put on in two pieces. The pipe requires to be so made that it can be pushed in against the cylinder in order to accommodate its outer attachment. It is not necessary to make provision at the outer end of the trunnion-pipe for the falling of the trunnion by wear, as the wear is so small as to be of no practical moment. The thickness of metal of the cylinder is 1½ inch; the thickness of the top and bottom of the belt is 2½ inches in the wake of the trunnion, and 2 inches in other places. The diameter of the hole in the belt is 18 inches; the internal diameter of the steam-pipe is 13 inches; and the diameter over the flange for the attachment of the trunnion is 30½ inches. The interior of the belt in the wake of the trunnion measures 29 inches deep and 4½ inches wide. The crank-shaft bearings are 12 inches in diameter and 13 inches long. The paddle-wheels are overhung, and the outer journal of the shaft is 14 inches diameter, and 14 inches long; the part on which the centre is fixed, from whence the arms diverge, being 16 inches diameter, and 24 inches long. When the paddle is overhung, the shaft increases in size at the outer end, in-

stead of diminishing as in other cases. The diameter of the wheels is 22 feet; the floats are 2 feet broad and 9 feet long, and have a dip of 4 feet 7 inches from the load water-line, at which point the vessel draws 11 feet of water. The crank-pin is 9 inches in diameter, and has a length of bearing for the connecting rod of 14 inches. The diameter of the Trident's piston-rod is 7½ inches; we think the introduction of larger piston-rods than have yet been introduced in oscillating engines would be an improvement, and would add to the durability of the engines. Each cylinder measures 8 feet 1 inch across from centre to centre of trunnion, and 11 feet 6 inches from the level of the trunnion to the level of the shaft.

The position of the trunnion should be a little above the centre of gravity of the cylinder, so that it will have no tendency to tilt over when the piston-rod is disengaged from the crank-pin, and very little tendency at the same time when pushed over to resume the perpendicular. The plan of attaching a weight to one side of the cylinder to balance the valve-casing is now discontinued in the best engines, and two valves are employed which balance one another. These valves are placed one on each side of the trunnion, so that they may both be wrought by the same eccentric. If the curved eccentric frame were discarded, the eccentric rod might be attached immediately to a cross-head, from the ends of which the two valve-rods descended, and the intermediate geer at present used might thus be dispensed with.

Engines applied direct to the screw.—It requires but little penetration to foresee that the present species of marine engine must be given up if the screw propeller gains a general introduction, for the engines will in that case be coupled immediately to the screw-shaft, which, as it requires to revolve much more quickly than a paddle-shaft, involves a greatly increased speed of piston. Small engines, with the pistons moving at a quick speed, will exert the same power as large engines moving with a slow speed; and small engines, by being applied to the screw-shaft direct, may be made to do the work of large ones. This is a manifest advantage to steam navigation, as a vessel may be constructed with very large power without being inconveniently burdened with the weight of the engines; and it is also an advantage to the makers of engines, who will thus be enabled to produce a given power at a less cost. The only impediment to the general introduction of this system lies in the difficulty of driving the air-pump at a high speed without causing the valves to strike so hard as to wear themselves out very quickly. The difficulty may be met by making the air-pump piston without valves, and opening and shutting the foot valve passage by means of a slide-valve, the motion for working which is derived from the eccentric-rod. The delivery valve must still be opened by the pressure of water in the pump; but it may be made to consist of a piston valve with skewed ports of the usual form, and it may be closed, or the piston be brought opposite to the ports by means of a pendulum weight at the end of a lever moving outside. Most of the engines at present in course of construction for direct application to the screw, are made with four cylinders lying horizontally with two cranks upon the screw-shaft, to which the connecting rods are attached, the connecting rods being joined to the top of the piston-rods, as in the Gorgon, or locomotive construction. Oscillating engines, laid at an angle of 45°, and joined to a single crank on the shaft, have in some cases been employed; and we think this arrangement is upon the whole the preferable one. The air-pump may be made double-acting, and may be worked from the same crank-pin to which the piston-rods are attached; the pin, however, being made eccentric in the part to which the air-pump rod is attached, in order to give the pump a shorter stroke than the piston. The crank and crank-pin will, if this arrangement be adopted, be stronger if made in the same piece, and the neck of the shaft from which the crank overhangs must be made stronger than usual. If the air-pump be made double-acting, as appears to be the preferable practice, its diameter may be very small, but the foot and delivery valve passages must be larger than usual in proportion to the size of the pump. If a piston valve be adopted for the delivery valve, it will be expedient to balance the valve by means of a counterweight, as is done in case of the steam-valve, adding then a pendulum, or a short crank pulled into the vertical position by a rod loaded with a weight, the end of the rod being suitably guided by a swivelling eye, in order to bring back the valve, or retain the piston opposite the ports until the pressure comes on. It is clear that, if this arrangement be adopted, the thrust of the shaft forwards, which in the case of the Rattler screw steamer is equivalent to a weight of four tons, cannot be sustained by the end of the shaft; and the best arrangement appears to be, to receive the thrust upon a collar on the shaft, which works within an oil cylinder,—oil being forced continually by a small pump worked by the engine between the end of the oil cylinder and the collar, until the collar is forced back with a pressure equal to that of the forward thrust. It is not expedient, however, to trust to the oil alone; and, therefore, between the collar and the bottom of the oil cylinder, and also between the collar and the top of the oil cylinder—so as to give security for backing—rollers carried by rings, as in the case of the rollers of a swivel bridge, or railway turn-table, should be interposed. These rollers should be as numerous as can be conveniently applied; they should each touch only in one point; should be made narrow, and several of these narrow rollers should be set upon the same spindle, so as to increase the quantity of the bearing surface. The collar and ends of the oil cylinder should consist of plates of hardened steel, and the rollers should also be of hardened steel, and be all made of exactly the same diameter. The oil cylinder would have to be supplied with a safety-valve on each side of the collar, so that any surplus oil sent in by the pump would be able to escape into a small tank, out of which the pump would draw. By these expedients, the thrust of the screw may be effectually and satisfactorily counteracted. It appears expedient to tooth out the eye of the collar, and to make it of sufficient length to serve as a coupling-box, the end of the shaft proceeding from the screw to the collar being similarly toothed, and fixed fast into the collar; while the end of the shaft proceeding from the collar to the engine is toothed in the same fashion, but so fitted as to slide endways in the collar. By this arrangement, should the oil cylinder yield slightly, or the rollers wear, the engine framing will still be preserved from the forward strain; the only effect of such accidents being to make the engine shaft slip somewhat further into the collar. The edge of the collar would be furnished with cupped leathers upon each side, of the same description as those used for the rams of hydraulic presses.

Centres and lengths of rods.—In fixing the positions of the centres, it appears to be the most conve-

nient way to begin with the main centre. The height of the centre of the cross-head at half-stroke above the plane of the main centre, is fixed by the drawing of the engine, which gives the distance from the centre of cross-head centre at half-stroke, to the flange of the cylinder; and from thence it is easy to find the perpendicular distance from the cylinder-flange to the plane of the main centre, merely by putting a straight-edge along level, from the position of the main centre to the cylinder, and measuring from the cylinder-flange down to it, raising or lowering the straight-edge until it rests at the proper measurement. The main centre is in that plane, and the fore and aft position is to be found by plumbing up from the centre line on the sole-plate. To find the paddle-shaft centre, plumb up from the centre line marked on the edge of the sole-plate, and on this line lay off from the plane of the main centre the length of the connecting rod, if that length be already fixed; or otherwise the height fixed in the drawing of the paddle-shaft above the main centre. To fix the centre for the parallel-motion shaft, when the parallel bars are connected with the cross-head, lay off on the plane of main centre the length of the parallel bar from the centre of the cylinder, deduct the length of the radius crank, and plumb up for the central line of motion shaft; lay off on this line, measuring from the plane of main centre, the length of the side-rod; this gives the centre of parallel-motion shaft, when the radius-bars join the cross-head, as is the preferable practice where parallel-motions are used. The length of the connecting rod is the distance from the centre of the beam when level, or the plane of the main centre, to the centre of the paddle-shaft. The length of the side-rods is the distance from the centre line of the beam when level, to the centre of the cross-head when the piston is at half-stroke. The length of the radius-rods of the parallel motion is the distance from the point of attachment on the cross-head or side-rod, when the piston is at half-stroke, to the extremity of the radius-crank, when the crank is horizontal; or, in engines with the parallel motion attached to the cross-head, it is the distance from the centre of the pin of the radius-crank, when horizontal to the centre of the cylinder.

How to set the parallel motion.—In marine engines, having fixed the centre of the parallel-motion shaft in the manner just described, it only remains to put the parts together when the motion is attached to the cross-head; but when the motion is attached to the side-rod, the end of the parallel bar must not move in a perpendicular line, but in an arc, the versed sine of which bears the same ratio to that of the side-lever that the distance from the top of the side-rod to the point of attachment bears to the total length of the side-rod.

The parallel motion when put in its place should be tested by raising and lowering the piston by means of the crane: first set the beams level, and shift in or out the motion-shaft, plummer-blocks, or bearings, until the piston-rod is upright. Then move the piston to the two extremes of its motion: if at both ends the cross-head is thrown too much out, the stud in the beam to which the motion side-rod is attached is too far out, and must be shifted nearer to the main centre: if at the extremities the cross-head is thrown too far in, the stud in the beam is not out far enough. If the cross-head be thrown in at the one end and out equally at the other, the fault is in the motion side-rod, which must be lengthened or shortened to remedy the defect.

How to set the slide-valves.—The first thing is to ascertain whether the eccentric-rod is of the right length. To determine this, put the valve in the middle of its stroke, so that both ports are covered equally, and fix it in that position. Next, turn round the eccentric on the shaft until the eccentric-rod has reached the furthest point of its travel *from* the shaft, and square up from the side of the eccentric-pin a line upon the rod. Turn round the eccentric again until the eccentric-rod reaches the end of its travel *towards* the shaft, and square up another line on the rod *from the other side* of the pin. If the eccentric notch be equally distant from the lines thus marked upon the eccentric-rod, the rod is of the right length; but if the notch be too far down upon it, the rod requires to be shortened; and if too far up, to be lengthened—in each case to an extent equal to the deviation of the notch from the central line. Thus, if on trial, the notch be found to be half an inch nearer to the lower than to the upper line, the notch will require to be shifted up a quarter of an inch, to place it midway between the lines; and to do this, the rod must be *shortened* a quarter of an inch; whereas, if the notch be half an inch nearer the upper than the under line, the rod will require to be *lengthened* a quarter of an inch, and so on in all other proportions.

The right length for the eccentric-rod having been thus obtained, and the rod having been adjusted thereto, the next step is to set the crank perpendicular. In a workshop this is easily done by a plumb-line, but in a steam-vessel recourse must be had to another method. Find on the sole-plate, or cylinder-mouth if a direct action engine, the transverse centre line answering to the centre of the shaft. Describe on the large eye of the crank a circle of the size of the crank-pin, and lay off in a fore and aft direction from the transverse centre line on cylinder-mouth or sole-plate, a distance equal to the radius or half diameter of the crank-pin. Stretch a line from the point thus marked off to the edge of the circle described on the large eye of the crank, and turn round the paddle-wheels until the crank-pin just touches the stretched line—the crank will then be perpendicular, and may be set by this method either on top or bottom centre.

The crank having been set in a perpendicular position while the valve is set and fixed with the amount of lead it is intended to give, the eccentric has only to be turned round upon the shaft until the notch comes opposite to the pin and the rod falls into geer, to determine the right position of the eccentric on the shaft. The situation of the eccentric may then be marked upon the shaft, and the catches fitted on in the usual way. The valve may first be set for going ahead, and may then be set for going astern,—shifting round the eccentric to the opposite side of the shaft until the rod again falls into geer. The position answerable to going ahead in some engines will be that answerable to going astern in others, depending on the way in which the engines are placed, the arrangement of the levers, and the kind of valve employed. It is necessary to recollect that it is the catches which drive the eccentric, and not the eccentric the catches, mistakes having sometimes arisen from forgetfulness of this condition.

It is impossible to give any general rule for finding the length of the valve levers or the throw of the valve. In most engines, however, the travel of the valve is twice the depth of the port, and the throw

of the eccentric is equal to the travel of the valve, so that motion is neither gained nor lost by the levers. In engines which do not operate expansively, the depth of the valve face is equal to the depth of the port; but all modern engines have a certain amount of lap or cover on the steam side; and some on the eduction side also. In the Thames and Medway steamers by Messrs. Maudslay, the travel of the valve is 16 inches, and the length of valve lever 8¾ inches; depth of port 6 inches; length of port 26 inches; distance from upper edge of upper port to under edge of under port, 8 feet 9¾ inches; and distance between extreme edges of valve faces, 8 feet 9½ inches; so that instead of there being cover upon the eduction side, the valve is one-eighth of an inch short at each end, and will not cover the ports in any position. In some engines the upper face is made narrower than the under face. In Messrs. Maudslay's 50-horse power engines, the breadth of the port is 3 inches, and its length 15 inches; the breadth of the lower valve face is 5 inches, and of the upper one, 4⅝ inches. In the 48-inch cylinders of the same makers, the size of port is 3¼ inches by 18 inches; in the 54-inch cylinders the size of port is 20 inches by 4 inches; the valve faces, 8 inches, and 7½ inches broad; and the length of the travel 11 inches. Other makers adopt different modes of setting the valves—we believe with little difference in the efficiency of the engine. We must refer the reader to the investigations and rules we have already given respecting slide-valves, as the best guide we can furnish for fixing the lap, lead, and other elements, in the absence of a uniformity of practice.

How to put the engines into a steamship.—First, measure across from the inside of paddle-bearers to the centre of the ship, to make sure that the central line, running in a fore and aft direction on the deck or beams, usually drawn by the carpenter, is really in the centre; and if it is not, make a fore and aft line or mark that is in the centre. Stretch a line across between the paddle-bearers in the direction of the shaft: to this line in the centre of the ship where the fore and aft mark has been made, apply a square with arms six or eight feet long, and bring a line, stretched perpendicularly from the deck to the keelson, accurately to the edge of the square; the lower point of the line where it touches the keelson will then be immediately beneath the mark made on the deck. If this point does not come in the centre of the keelson, it will be better to shift it a little, so as to bring it to the centre, altering the mark on the deck correspondingly, provided either paddle-shaft will admit of this being done—one of the paddle-brackets being packed behind with wood, to give it an additional projection from the side of the paddle-bearer. Continue the line fore and aft upon the keelson as nearly as can be judged in the centre of the ship; stretch another line fore and aft through the mark upon the deck, and look it out of winding with the line upon the keelson. Fix upon any two points equally distant from the centre, in the line stretched transversely in the direction of the shaft; and from those points as centres, and with any convenient radius, sweep across the fore and aft line to see that the two are at right angles; and if not, shift the transverse line a little to make them so. From the transverse line next let fall a line upon each outside keelson, bringing the edge of the square to the line, the other edge resting on the keelson. A point will thus be got on each outside keelson perpendicularly beneath the transverse line running in the direction of the shaft, and a line drawn between those two points will be directly below the shaft. To this line the line of the shaft marked on the sole-plate has to be brought, care being taken at the same time, that the right distance is preserved between the fore and aft line upon the sole-plate, and the fore and aft line on the central keelson. Before any part of the machinery is put in, the keelsons should be dubbed fair and straight, and be looked out of winding by means of two straight-edges. The art of placing engines in a ship is more a piece of plain common sense than any other feat in engineering; and every man of intelligence may easily settle a method of procedure for himself. Plumb-lines and spirit-levels, it is obvious, cannot be employed on board a vessel; and the problem consists in so placing the sole-plates, without these aids, that the paddle-shaft will not stand awry across the vessel, nor be carried forward beyond its place by the framing shouldering up more than was expected. As a plumb-line cannot be used, recourse must be had to a square; and it will signify nothing at what angle with the deck the keelsons run, so long as the line of the shaft across the keelsons is squared down from the shaft centre. The sole-plates being fixed, there is no difficulty in setting the other parts of the engine in their proper places upon them. The paddle-wheels must be hung from the top of the paddle-box, to enable the shaft to be rove through them; and the cross-stays between the engines should be fixed in when the vessel is afloat. To try whether the shafts are in a line, turn the paddle-wheels, and try if the distance between the cranks is the same at the upper and under, and the two horizontal centres; if not, move the end of the paddle-shaft up or down, or backwards or forwards, until the distance between the cranks at all the four centres is the same.

Miscellaneous remarks respecting marine-engines.—The cylinders should be felted, and then cased with wood that has been baked until it will shrink no longer. The steam-pipes should be cased in the same way, and the boilers should be felted, and then covered with sheet-lead, soldered at every joint. The whole of the screws about the engine should be made according to a uniform system of threads, and the nuts of the same sized bolts should also be of the same size, so that a single spanner will serve for those nuts. The spanners intended for polished nuts should be close and single-ended, and they should be themselves polished and case-hardened, and ranged in regular order on one of the engine-room bulkheads. A pair of brass-sheaved blocks for raising the cylinder cover, and another smaller pair for raising the air-pump cover, should be provided; and a strong screw, with a large eye at the end, for raising the paddle-wheel. Strong spanners should also be provided for the holding-down bolts, with eyes at the end, to which a tackle may be applied; and a box-key for tightening down the bolts of the paddle-shaft plummer-blocks through the crank-hatch. Tallow kettles are little needed if the pistons and cylinder stuffing-boxes have metallic packings. Oil-cans and lamps should be ranged on a shelf in separate stands, so that they cannot fall off when the vessel rolls. For every article of engine-room furniture there should be a convenient and conspicuous place; and if there be any articles of spare geer, they should be all kept *in sight.* Unless this be done, they are almost sure to be eaten up with rust, as neglect generally follows their stowage in an unfrequented or inaccessible place.

In most steam-vessels a good deal of trouble is caused by the holding-down bolts, which are generally

made of iron. Sometimes they go through the bottom of the ship, and at other times they merely go through the keelson, a recess being made in the floor or timbers to admit of the introduction of a nut. The iron, however, wears rapidly away in both cases, even though the bolts are tinned; and it has been found the preferable method to make such of the bolts as pass through the bottom, or enter the bilge, of Muntz's metal, or of copper. In side-lever engines four Muntz's metal bolts may be put through the bottom at the crank end of the framing of each engine, four more at the main centre, and four more at the cylinder, making twelve through bolts to each engine; and it is more convenient to make these bolts with a nut at each end, as in that case the bolts may be dropped down from the inside; and the necessity is obviated of putting the vessel on very high blocks in the dock, in order to give room to put the bolts up from the bottom. The remainder of the holding-down bolts may be of iron; and may, by means of a square nut, be screwed into the timber of the keelsons as wood screws, the upper part being furnished with a nut, which may be screwed down upon the sole-plate, so soon as the wood screw portion is in its place. If the cylinder be a fixed one, it should be bolted down to the sole-plate by as many bolts as are employed to attach the cylinder-cover, and they should be of copper or brass, in any situation that is not easily accessible. In well-formed bolts the spiral groove penetrates about one-twelfth of the diameter of the cylinder, so that the diameter of the solid cylinder which remains is five-sixths of the diameter over the thread. The strain to which iron may be safely subjected in machinery, is one-fifteenth of its utmost strength, or 4000 pounds on the square inch, so that 2180 pounds may be sustained by a screw an inch in diameter at the outside of the threads. The strength of the holding-down bolts, therefore, may easily be computed, when the elevating force of the piston or main centre is known, but it is expedient very much to exceed this strength in practice, on account of the elasticity of the keelsons, the liability to corrosion, and other reasons.

A very useful species of oil-cup is now employed in a number of steam-vessels; and which, it is said, accomplishes a considerable saving of oil, at the same time that it more effectually lubricates the bearings. A ratchet-wheel is fixed upon a little shaft which passes through the side of the oil-cup, and is put into slow revolution by a pendulum attached to it outside; and in revolving it lifts up little buckets of oil and empties them down a funnel upon the centre of the bearing. Instead of buckets, a few short pieces of wire are sometimes hung on the internal revolving wheel, the drops of oil which adhere to them on rising from the liquid being deposited upon a high side set upon the funnel, and which in their revolution the hanging wires touch. By this plan, however, the oil is not well supplied at slow speeds, as the drops fall before the wires are in the proper position for feeding the journal. Another lubricator consists of a cock or plug inserted in the neck of the oil-cup, and set in revolution by a pendulum and ratchet-wheel, or any other means. There is a small cavity in one side of the plug, which is filled with oil when that side is uppermost, and delivers the oil through the bottom-pipe when it comes opposite to it. In some cases bearings heat from making a cruciform groove in the top brass for the distribution of the oil, the effect of which is to leave the top of the bearings dry. In the case of revolving journals, the plan of cutting a cruciform channel for the distribution of the oil does not do much damage; but in other cases, as in beam-journals for instance, it is most injurious, and the brasses cannot wear well wherever the plan is pursued. The right way is to make a horizontal groove along the brass where it meets the upper surface of the bearing, so that the oil may be all deposited on the highest point of the journal, leaving the force of gravity to send it downwards. This channel should of course stop short a small distance from each flange of the brass, otherwise the oil would run out at the ends.

The paddle-shaft, where it passes through the vessel's side, is usually surrounded with a lead stuffing-box, which will yield if the end of the shaft falls. This stuffing-box prevents leakage into the ship from the paddle-wheels, but it is expedient as a further precaution to have a small tank on the ship's side immediately beneath the stuffing-box, with a pipe leading down to the bilge to catch and conduct away any water that may enter. The bearing at the outer end of the paddle-shaft is sometimes supplied with tallow forced into a hole in the plummer-block cover, as in the case of water-wheels; but for vessels intended to perform long voyages, it is preferable to have a pipe leading down to an oil-cup above the journal, from the top of the paddle-box, through which pipe oil may at any time be supplied. The eccentrics should be fitted with pans beneath them to catch the oil which falls. In vessels fitted with Hall's condensers, the pistons and stuffing-boxes must be supplied with oil instead of tallow, as the tallow congeals in the pipes of the condensers and chokes them up. The bolts for holding on the paddle-floats should be made extra strong on account of the corrosion to which they are subject, and the nuts should be made large and should be square, so that they may be effectually tightened up even though the corners are worn away by corrosion. Paddle-floats, when consisting of more than one board, should be bolted together edgewise by means of bolts running across their whole breadth; they should not overhang the ring much at the outside of the wheel, else they will be very liable to be broken off when the wheel strikes the water heavily. The aftermost paddle-beam should come as close as possible to the wheel to prevent the spray from being carried up. The angular pieces or wales running from the extremities of the paddle-beams to the back of the deck-houses, are best when fitted with iron gratings, as wooden gratings are liable from their greater opposing surface to be carried away. The brackets supporting the paddle-box steps should consist of circular pieces running round the paddle-box from step to step, as when put on with isolated brackets the steps are liable to be carried away by the sea. The funnel shrouds should consist of rope of the same dimensions as the shrouds of the mainmast, but a few feet at the top should consist of chain, as rope close to the funnel would be burned.

It is very difficult to fix engines effectually which have once begun to work in the ship, for in time even the surface of the keelsons on which the engines bear becomes worn uneven, and the engines necessarily rock upon it. As a general rule, the bolts attaching the engine to the keelsons are too few and of too large a diameter; it would be greatly preferable to have smaller bolts and more of them. Twelve very strong brass or copper holding-down bolts going through the vessel's bottom are sufficient for a side-lever engine, and supposing the vessel to be a wooden one; but there should be a large

number of wood screws securing the sole-plate to the keelson, and a large number of bolts securing the various parts of the engine to the sole-plate. In iron vessels, holding-down bolts passing through the bottom are not expedient, and then the engine has merely to be secured to the iron plate of the keelsons, which are made hollow and admit of the most effectual attachment of the engine. Where the framing is of cast-iron, it is very expedient to have one piece running across the end of the engines clear of the connecting-rod, so as to bind the whole of the frames together, and a cross should extend horizontally between the intermediate frames immediately beneath the paddle-shaft, so as to counteract the disturbing action of the connecting-rods. At the cylinder jaw, if the frame works, the best expedient appears to be the introduction of a number of steel tapered bolts, the holes having been previously bored out; and if the flanges be thick enough, square keys may also be introduced, half into the one flange and half into the other, so as to receive the strain. If the jaw cracks or breaks away, a malleable iron hoop may be applied round the cylinder, and that will in all cases be the preferable expedient, where from peculiarities of structure it can be as easily done as introducing bolts and keys. If the engines rock very much in the vessel, and are defective in other respects, it will be the preferable plan to take them out and thoroughly repair them, preparatory to their re-introduction; and the keelsons will then have to be dubbed afresh, and the sole-plates fitted carefully to them. A common practice is to let the sole-plates rest on the bolt-heads, and then to fit in wedges all round until the vacuity is filled; but it is preferable to fit the plates down solid upon the wood, and such is the practice of the best engineers.

Rust joints are not now much used in marine-engines, yet it is necessary that we should state how they are made. One ounce of sal-ammoniac in powder is added to 18 ounces or a pound of borings of cast-iron, and a sufficiency of water is added to wet the mixture thoroughly, which should be done some hours before it is wanted for use. Some persons add about half an ounce of flowers of brimstone to the above proportions, and a little sludge from the grindstone trough. This cement is caulked into the joints with a caulking-iron, about three-quarters of an inch wide, and one-quarter of an inch thick; and after the caulking is finished, the bolts of the joint may be tried to see if they cannot be further tightened. The skin of the iron must in all cases be broken where a rust joint is made, and if the place be greasy, the surface must be well rubbed over with nitric acid, and then washed with water until no grease remains. The oil about engines has a tendency to damage rust joints by recovering the oxide. Coppersmiths stanch the edges of plates and the rivets by means of a cement formed of pounded quicklime and serum of blood, or white of egg, and in copper boilers such a substance may be useful in stopping the impalpable leaks which sometimes occur, though Roman cement appears to be nearly as effectual. It would be worth trying, however, whether the mixture would not prevent the internal corrosion of boilers, if laid on as a paint. Wire gauze smeared with white or red lead and interposed between surfaces made quite true, appears to be the best description of joint yet introduced, and has now become identified with the practice of the best engineers.

Metals used in the construction of engines.—The general ambition in making cylinders is to make them sound and hard; but it is expedient also to endeavor to make them tough, so as to approach as nearly as possible to malleable iron. This may best be done by mixing in the furnace as many different kinds of iron as possible; and it may be set down as a general rule in iron-founding, that the greater the number of the kinds of iron entering into the composition of any casting, the denser and tougher it will be. The constituent atoms of different kinds of iron appear to be of different sizes, and the mixture of different kinds maintains the toughness which adds to the density and cohesion. Hot-blast iron was at one time generally believed to be weaker than cold-blast, but it is now found to be the stronger of the two. The cohesive strength of unmixed iron is not in proportion to its specific gravity; and its elasticity and power to resist shocks appear to become greater as the specific gravity becomes less. We give here the average results of a number of experiments made in Scotland upon the strength of iron. The bars experimented on were one inch square and three feet long. Coltness iron (No. 1) bore a weight of 636 pounds, and the same iron (No. 3) bore 649 pounds; Gartsherrie (No. 1) bore 633 pounds; Shott's, (No. 1,) 594 pounds; Wilsontown, (No. 1,) 706 pounds, and (No. 2) 718 pounds; Pintwyn, (No. 1,) 681 pounds; Calder, (No. 3,) 765 pounds; Govan, (No. 3,) 645 pounds; Bumbow, (No. 2,) 734 pounds. Mixed irons are found to be stronger. Coltness and Gartsherrie (No. 1) bore 842 pounds; Coltness, Castlehill, Shott's, and Gartsherrie, (No. 1,) 639 pounds; Coltness, (No. 1,) and Bumbow, (No. 2,) 677 pounds. A mixture consisting of 2 tons Pintwyn, (No. 1,) 4 tons Pintwyn, (No. 2,) 5 tons of Wilsontown, (No. 2,) 2 tons of Wilsontown, (No. 3,) 5 tons of Calder, (No. 2,) and 4 tons of Calder, (No. 3,) bore 1,008 pounds; and a miscellaneous lot of old cast-iron of the cold-blast manufacture, from Wilsontown, bore 1,500 pounds. Numbers 3 and 4 are the strongest irons in most cases: iron remelted in a cupola is not so strong as when remelted in an air-furnace; and when run into green sand it is not reckoned so strong as when run into dry sand or loam. The quality of the fuel, and even the state of the weather, exerts an influence upon the quality of the iron. Smelting furnaces on the cold-blast principle have long been known to yield better iron in winter than in summer, probably from the existence of less moisture in the air; and it would probably be found to be an improvement in iron-founding if the blast were to pass through a vessel containing muriate of lime, by which the moisture in the air would be extracted. The secret of making fine-skinned castings lies in using plenty of blackening. In loam and dry sand castings the charcoal should be mixed with thick clay water, and applied until it is an eighth of an inch thick, or more; the surface should then be very carefully smoothed or sleeked, and if the metal has been judiciously mixed, and the mould thoroughly dried, the casting is sure to be a fine one. Dry sand and loam castings should be as much as possible made in boxes; the moulds may thereby be more rapidly and more effectually dried, and better castings will be got, with a less expense.

In the malleable iron work of engines scrap-iron has long been used, and considered preferable to other kinds; but if the parts are to be case-hardened, as is now the usual practice, the use of scrap-iron is to be reprehended, as it is almost sure to make the parts twist in the case-hardening process. In

case-hardening, iron absorbs carbon, which causes it to swell: some kinds of iron have a greater capacity for carbon than other kinds, and in case-hardening they will swell more; and any such unequal enlargement in the constituent portions of a piece of iron will cause it to change its figure. In some instances case-hardening has caused such a twisting of the parts of an engine, that they could not afterwards be fitted together. It is preferable, therefore, to make such parts as are to be case-hardened to any considerable depth of Lowmoor iron, which, being homogeneous, will absorb carbon equally, and will not twist.

Piston-rods are now very generally made of steel, and are obtained of the requisite size and quality from the rolling-mill. Steel is made almost exclusively from Dannemora iron: the bars are arranged in a furnace about 14 feet long; a layer of charcoal is spread over the bottom, then a layer of bars, and so on until about 10 tons of iron have been introduced. The top is covered with charcoal, over which is a layer of sand, and above that a layer of slush from the grindstone trough, applied wet; the object of which is entirely to exclude the air. The fire is then lighted, and in about a week the iron will have increased in weight a one hundred and fiftieth part, and be found converted into blistered steel. These bars may then be fagoted and tilted, so as to form steel articles of any size. In the operation of case-hardening the same process is carried on as in converting iron into steel, but it is only continued for such a time as to enable the charcoal to penetrate to a moderate depth. In our judgment all the malleable iron parts of a marine steam-engine should be case-hardened, as they cannot then be so easily defaced, by hammer marks or otherwise, and will be much less liable to rust. The more unwieldy portions may be case-hardened by prussiate of potash, a salt made from animal substances, composed of two atoms of carbon and one of nitrogen, and which operates on the same principle as in the case of case-hardening by means of charcoal. The iron is heated in the fire to a dull-red heat, and the salt is either sprinkled upon it or rubbed on in the lump, or the iron is rolled in the salt in powder; the iron is then returned to the fire for a few minutes, and immersed in water. By some persons the salt is supposed to act unequally, as if there were greasy spots upon the iron which the salt refused to touch, and the effect under any circumstances is exceedingly superficial; nevertheless, upon all parts not exposed to wear, a sufficient coating of steel may be obtained by this process. The most common plan of case-hardening consists in inserting the articles among horn or leather cuttings, bone-dust, or animal charcoal, in an iron box provided with a tight lid, which is then put into a furnace, and kept hot for a period answerable to the depth of steel required. In some cases the plan pursued by the gunsmiths may be employed with convenience. The article is inserted in a sheet-iron case, amid bone-dust, often not burned; the lid of the box is tied on with wire, and the joint luted with clay, and the box is heated to redness as quickly as possible, and kept half an hour at a uniform heat. Its contents are then suddenly immersed in cold water. The carbonaceous lining in the inside of old retorts is sometimes used in case-hardening with good effect.

Steel is hardened by heating and cooling it suddenly, and softened by heating and cooling it slowly. A thin blade of steel, if heated, and placed between the cold hammer and anvil, will become extremely hard; whereas a thick piece of steel would not be made hard by such a mode of treatment. Mercury has been proposed, instead of water, for hardening steel, but its use is not attended with sensible advantage. Salt and water is also used, but the articles immersed in it are liable to rust, unless afterwards steeped in lime-water. Water which has been long used for tempering is supposed to be preferable to fresh water, and if the steel is harsh the chill is taken off the water. In the case of thin edge-tools the water is sometimes covered with a film of oil, but it is a question whether plain water is not preferable. The file-makers medicate the water they use for tempering, and the method of doing so forms one of the secrets of the trade; but it appears probable that a little white arsenic is the chief addition they make. A common practice with some steel articles is to make them in the first instance as hard as possible, and then to soften them somewhat, or let them down, as it is called, by heating them to a certain temperature, which is indicated by the color they assume. A pale straw-color, which is indicative of a temperature of from 430° to 450°, is the color proper to tools for metal; a dark straw-color, 470° to 490°, is that suitable for tools for wood and for screw-taps; a brown-yellow, verging to a light purple, 500° to 530°, is the color suitable for hatchets and saws; and a dark blue, 550° to 600°, is the color for springs. Steel dies may be tempered by heating them to the color of sealing-wax, plunging them into naphtha heated to 200°, and so soon as ebullition ceases, plunging them into cold water. It appears to be the prevailing opinion among experienced machinists, that for the great majority of articles requiring to be tempered, plain cold water is the best agent, but that for small elastic works oil is preferable. For letting down large tools, a red-hot muffle is a convenient instrument, and is used in the Bank of England. Steel articles may be most effectually softened by exposing them to a high heat, imbedded in a mixture of charcoal and chalk. Steel that has been spoiled by overheating may be recovered by heating and quenching in water four or five times, carrying each to a somewhat less degree than the first excess, and finally the steel must be well hammered at a red heat, continuing the hammering until the steel is nearly cold.

Copper and zinc seem to mix in all proportions, and every addition of zinc increases the fusibility. The red color of copper slides into that of yellow brass at about 4 or 5 ounces to the pound, and remains little altered to about 8 or 10 ounces; after this it becomes whiter, and when 32 ounces of zinc are added to 16 of copper, the mixture has the brilliant silvery color of speculum metal, but with a bluish tint. The alloys with zinc retain their malleability and ductility well, to about 8 or 10 ounces to the pound; after this, the crystalline character begins to prevail. The alloy of 2 zinc and 1 copper may be crumbled in a mortar when cold. The ordinary range of good yellow brass, that files and turns well, is from about 4½ to 9 ounces to the pound. Brazing solders may be stated in the order of their hardness—3 parts copper and 1 part zinc, (very hard;) 8 parts brass and 1 part zinc, (hard;) 6 parts brass, 1 part tin, and 1 part zinc, (soft.) A very common solder for iron, copper, and brass consists of nearly equal parts of copper and zinc. Muntz's metal consists of 40 parts of zinc and 60 of copper. Any proportions between the extremes of 50 zinc and 50 copper, and 37 zinc and 63 copper, will roll and

work at the red heat, but 40 zinc to 60 copper are the proportions preferred. Bell-metal for large bells consists of 4½ ounces to 5 ounces of tin to the pound of copper. Tough brass for engine-work, 1½ pound tin, 1½ pound zinc, and 10 pounds copper. Brass for heavy bearings, 2½ ounces tin, ½ ounce zinc, and 1 pound copper. There is a great difference in the length of time brasses wear, as made by different manufacturers, but the difference arises as much from a different quantity of surface as from a varying composition of the metal. Brasses should always be made strong and thick, as when thin they collapse upon the shaft, and increase the friction and the wear.

A lining metal for bushes has latterly been introduced in the bushes of locomotive axles, and other machinery, composed of 1 pound of copper, 5 pounds regulus of antimony, and 50 pounds of tin, or other similar proportions, the presence of the tin being the only material condition. The copper is first melted, and the antimony is added, with a small portion of the tin, charcoal being strewed over the metal in the crucible, to prevent oxidation. The bush or article to be lined having been cast with a recess for the soft metal, is to be fitted to an iron, formed of the shape and size of the bearing or journal, allowing a little in size for the shrinkage; drill a hole for the reception of the soft metal, say from ½ to ¾ of an inch diameter; wash the parts not to be tinned with a clay wash, to prevent the adhesion of the tin; wet the part to be turned with alcohol, and sprinkle fine sal ammoniac upon it; heat the article till a fume arises from the ammonia, and immerse it in a kettle of Banca tin, care being taken to prevent oxidation. When sufficiently tinned the bush should be soaked in water, to take off any particles of ammonia that may remain upon it, as the ammonia would cause the metal to blow. Wash with fine pipe-clay and dry, then heat the bush to the melting point of tin, wipe it clean, and pour in the metal, giving it sufficient head as it cools; the bush should then be scoured with fine sand, to take off any dirt that may remain upon it, and it is then fit for use. This metal wears for a longer time than ordinary gun-metal, and its use is attended with very little friction. If the bearing heats, however, from the stopping of the oil-hole, or otherwise, the metal will be melted out.

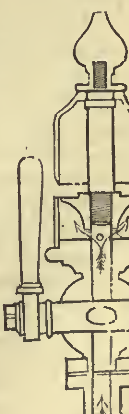
For details of *Boilers* see BOILERS.

Locomotive Engines—General features of the boiler. See BOILERS.

The shell, which is cylindrical, is attached to the smoke-box and fire-box by angle-iron; the end of the shell next the smoke-box is closed entirely by the tube-plate, but at the smoke-box end the water has free access quite round the internal fire-box, one side of which forms the tube-plate. The shell, external fire-box, and the smoke-box are always of iron, the thickness of plate being 5-16th in. in ordinary boilers of 3 feet to 3 feet 4 in. in diameter, though in some cases it is ⅜ in.; the pitch of rivets is 1⅞ in., and the diameter of rivets 11-16th in. The shell is sometimes made with flush joints, a band of iron covering the joint attached by two rows of rivets. The boiler plates should have their fibres running round the boiler instead of in the direction of its length, as the plate is somewhat stronger in that direction. The boiler is secured endwise by longitudinal stays, which are fastened by cutters to jaws attached to the end plates.

The blast-pipe is the eduction-pipe diminished in area at the mouth to such a degree as to cause the steam to issue with a great velocity, whereby a powerful draught through the fire is maintained by the steam rushing up the chimney. The area of the mouth of the blast-pipe varies in different engines, but an area of 1-22d of the area of the cylinder is a common proportion. A variable blast-pipe, the orifice of which may be increased or diminished in area, is now much used. One arrangement for this purpose consists of the application of a regulator plate at the top of the blast-pipe, with a hole through the centre of the plate, through which the nozzle of the blast-pipe passes. When this regulator plate is closed, the whole of the steam has to ascend through the central nozzle; but when the regulator is open, or partly open, a part of the steam escapes through the holes in it. Another plan consists in the application of a moveable plug within the blast-pipe, which may narrow the escape orifice to an annular space of small area, the plug being raised or lowered by a lever and rod. Stephenson's method of contracting the blast consists in making the nozzle of the pipe conical, and forming it to slide within the upright pipe, whereby an annular space is left for the escape of the steam around the nozzle when the nozzle is lowered.

1443.



The steam-whistle is generally placed upon the fire-box dome within convenient reach of the engineer. It consists of a cock, Fig. 1443, opening by four side holes into an annular chamber, whence the steam escapes through an annular aperture about 1-64th in. in width, striking in its exit the edge of a bell, fixed by a stem to the cock, whereby the sound is produced. The edge of this bell should be about 1-32d of an inch thick, and should be exactly over the opening, so that the issuing steam may impinge directly upon it. The metal should be of similar composition to that of clock bells. The whistle is sometimes jointed by running melted lead between its flange and the dome-plate; but it is better to fit the surfaces so truly together as to be steam-tight merely with the assistance of one thickness of fine canvas coated with red-lead or cement, for lead will always be found to decay by contact with high-pressure steam, making continual renovation necessary. This remark equally applies to the other joints connected to the shell of the boiler, such as the gage-tube, blow-off cocks, and feed-pipes.

To save the steam which is formed when the engine is stationary, a pipe is fitted to the boiler which conveys the steam at such times to the tender, where it heats the water and is itself condensed. This method of disposing of the steam is beneficial in descending inclined planes, when more steam is formed than is required for the use of the engine. A cock for emptying the boiler is usually fixed to the bottom of the fire-box; this cock should not be placed at the front end of the fire-box, as the foul water blown out of the boiler is thrown over the geering, which is injured by the sand getting into the bearings.

The *Fire-Bars* have always been a source of much expense in the locomotive-engine, as they burn out very rapidly, and have to be often renewed; from the rapid combustion going on over their upper surfaces, they become heated intensely throughout, causing them to throw off scale, and to bend under the weight of the fuel. The best remedy has been found to consist in making the bars very thin and deep, so as to keep their lower edges exposed to a cooling draught of air, and to diminish the area of metal conducting heat downwards from their heated upper edges. Fire-bars have given much satisfaction when made 4 inches deep, (parallel,) and full $\frac{5}{8}$ inch thick on the upper edge and $\frac{3}{8}$ inch on the lower edge. In some very large square fire-boxes, such as those used on the Great Western Railway, a diaphragm, or divisional 4-inch water-space, has been placed across the middle of the fire-box, with the view of obtaining increased heating surface.

The ash-box consists of a plate-iron tray, placed below the fire-box, to receive the burning ashes that drop from betwixt the fire-bars. In the earlier locomotives, no ash-boxes being used, the red-hot ashes were dispersed to a considerable distance by coming in contact with the wheels, and conflagrations were often thereby originated. The ash-box should be as large as convenient, and not less than 10 inches deep, otherwise it will materially impede the draught; but if of ample dimensions, and closed at the sides and back, it will increase the draught, particularly when running against a head wind, at which time a strong draught is required. A hanging shutter to open or close the front of the ash-box forms a good damper. The bottom of the ash-box is placed about 9 inches above the level of the rails, and should on no account be nearer than 6 inches, otherwise the engine cannot pass safely over stones or similar objects lying accidentally between the rails.

Tubes.—The tubes are generally formed of brass; the ferules by which they are secured are for the most part made of steel at the furnace end, and of malleable iron at the smoke-box end, and the holes in the tube-plates are tapered, so that the tubes bind them together. Great care should be taken in securing the tubes, as any neglect will be productive of much inconvenience. The ferules are found to be very injurious to freedom of draught, particularly in very small tubes; and to overcome this objection, the methods we have mentioned, and many others, have been tried for fastening the tubes in by riveting over or screwing into the tube-plates; but hitherto no method, except that of internal tube-rings, has been found to answer in the case of brass tubes; but we think it likely that, with wrought-iron tubes, internal tube-rings will be ultimately abandoned. Stephenson has frequently adopted iron tubes of late, in preference to brass, on the score of their greater cheapness and durability; and in some cases, where unusual attention has been paid to them, and pure water used, they have been found to answer very well. A common internal diameter of tubes is $1\frac{5}{8}$ in. If made very small, the tubes are liable to be choked by pieces of coke, and the sectional area will be inconveniently contracted, while, if made much larger, the heating surface will be unduly diminished. The number of tubes varies considerably in different boilers; in one species of locomotive in extensive use the number is 134, and the pitch $2\frac{1}{4}$ in. Sufficient space is left below the tubes for deposite, that it may not be in contact with the tubes and cause them to be burned: the extreme tube of the widest row is about the diameter of a tube from the boiler shell. In the long-boiler engines of Stephenson, from the volume of water contained in them, considerable time is required to get up the steam, even so much as three and a half hours where the ordinary engines take two hours, and they require great care in firing and feeding to prevent the steam running low.

Smoke-box and chimney.—The smoke-box door of many engines is hinged at the bottom, and is kept shut by means of handles and catches; but the position of the door when open is in that case inconvenient, as it prevents ready access to the tubes. In some of Stephenson's engines, the smoke-box door is in two leaves, which open like the doors of a house, overlapping at the centre, where they are closed by a bar, and at top and bottom by handles and catches. This door admits of the easy examination of the cylinders and valves. A small door is usually left near the bottom of the smoke-box, by which the accumulated cinders may be removed. The bottom of the smoke-box should not be below the ash-pan, or be much nearer the level of the rails than 18 inches, else the waste-water cocks of the cylinder projecting through it, would be liable to injury from objects lying on the line. The smoke-box is lower in freight engines than in passenger engines, on account of the driving wheels being smaller; and, being coupled with the other wheels, the cylinder has frequently to be inclined to let the moving parts work clear of the front axle.

The chimney must not stand more than 14 feet high above the rails. The sectional area of the chimney is about 1-10th of the area of fire-grate. The chimney is usually provided with a damper, similar to the disk throttle-valve of an ordinary engine; this is generally hung off the centre, and a hole is made in it for the top of the blast-pipe, which projects through it when it is closed. Another damper has been applied by Messrs. Rennie at the smoke-box end of the tubes, consisting of a sliding-plate perforated with holes, which when opposite the ends of the tubes will give a free current, and may be made to close them completely if required. Another kind of damper consists of an arrangement of thin bars similarly disposed to the laths of a Venetian blind; the plates being so hinged, that when placed with their edges to the tube-plate, they leave the flow of air through the tubes unimpeded, and when hanging down they close up the tubes, or they partially close the tubes in any intermediate position. By either of these arrangements, the hot air is retained for a longer period in contact with the tubes than if a simple damper were used, as each tube is virtually furnished with a hanging bridge which keeps in the hottest air and lets only the coldest flow out. An inconvenient degree of heat in the smoke-box is also prevented. The smoke-box is usually made of $\frac{1}{4}$ plate; the chimney of $\frac{1}{8}$th plate; the blast-pipe of $\frac{1}{8}$th copper, and the steam-pipe of 3-16th copper.

Framing.—In some engines the side-frames consist of oak, with iron plates riveted on each side. The guard-plates are in these cases of equal length, the frames being curved upwards to pass over the driving-axle. Hard cast-iron blocks are riveted between the guard-plates, to serve as guides for the axle-bushes. The side-frames are connected across at the ends, and cross-stays are introduced beneath the boiler to stiffen the frames sidewise, and prevent the ends of the connecting or eccentric rods from fall-

ing down, if they should be broken. The springs are of the ordinary carriage kind with plates, connected at the centre, and allowed to slide on each other at their ends. The upper plate terminates in two eyes, through each of which passes a pin, which also passes through the jaws of a bridle, connected by a double-threaded screw to another bridle, which is jointed to the framing: the centre of the spring rests on the axle-box. Sometimes the springs are placed between the guard-plates and below the framing, which rests upon their extremities. One species of spring which has gained a considerable introduction consists of a number of flat steel plates, with a piece of metal or other substance interposed between them at the centre, leaving the ends standing apart.

A common mode of connecting the engine and tender, is by means of a rigid bar with an eye at each end, through which pins are passed. Between the engine and tender, however, buffers should always be interposed, as their presence contributes greatly to prevent oscillation and other irregular motions of the engine. A bar is strongly attached to the front of the carriage on each side, and projects perpendicularly downwards to within a short distance of the rail, to clear away stones or other obstructions that might occasion accidents if the engine ran over them. The axles bear only against the tops of the axle boxes, which are generally of brass; but a plate extends beneath the bearing to prevent sand from being thrown upon it. The upper part of the box in most engines has a reservoir of oil, which is supplied to the journal by two tubes and siphon wicks. Stephenson uses cast-iron axle boxes with brasses, and grease instead of oil, which is fed by the heat of the bearing melting the grease, and causing it to flow down through a hole in the brass. All the engines with outside bearings have inside bearings also; they are supported by longitudinal bars, which serve also in some cases to support the piston guides: these bearings are sometimes made so as not to touch the shaft, unless in the event of its breaking.

Steam-dome pipes and regulator.—The steam-dome, or separator, from the upper part of which the supply of steam is obtained, is now generally placed over the fire-box; and in Bury's and Stephenson's engines it forms a part of the external shell of the fire-box; whilst in the engines used on the Grand Junction Railway, it consists of an independent cylindrical vessel, attached to the low roof of the fire-box. Either plan, this latter or Bury's, is perfectly safe and strong, without the addition of stay-rods; but Stephenson's dome presents a large extent of flat surface, from the roof of the internal fire-box up te the arched roof of the external fire-box; and this flat surface requires to be powerfully stayed by angle-irons and tension-rods. We remember an instance in which the accidental omission of one of the numerous tension-rods led to the forcing out and partial explosion of the side of the fire-box, showing how much depends on the circumstances of these rods, with their joints and pins, remaining sound and uninjured from corrosion or other source of injury or decay. In this respect the round fire-box, with its dome, has the advantage of superior strength and safety. A large steam-dome is found to be the most efficacious mode yet tried for preventing the evil of priming or damp steam; but no height of dome will entirely prevent it if there be not space enough left above the tubes in the cylindrical part of the boiler to allow the free passage of the steam along to the fire-box and dome, while an excessive height of dome is also found to produce an unsteady motion of the engine, by causing the machine to be top-heavy. A height of about 2 feet 6 inches above the cylindrical part of the boiler is found to give satisfactory results in practice, and to lead to the production of as pure steam as any greater altitude could secure. In some engines the steam is withdrawn from a dome placed at the smoke-box end of the boiler, into which the steam-pipe rises. It is thought that the ebullition being less violent at this point, the steam will thus be more effectually dried. The steam-pipes are made either of iron or copper; and of these, iron best withstands the high temperature of the smoke-box and the impact of the cinders, but it is liable to internal corrosion. The steam-pipe, after entering the smoke-box, divides into two branches, one passing down each side of the smoke-box so as to leave a free space for cleaning the tubes, and also to avoid as much as possible the impact of the hot air and cinders; but in some engines the steam-pipe descends vertically, which is somewhat inconvenient in practice. The area of the steam-pipe is one-sixth to one-eighth of the area of cylinder, and the branch steam-pipes are each about one-tenth of the area of cylinder.

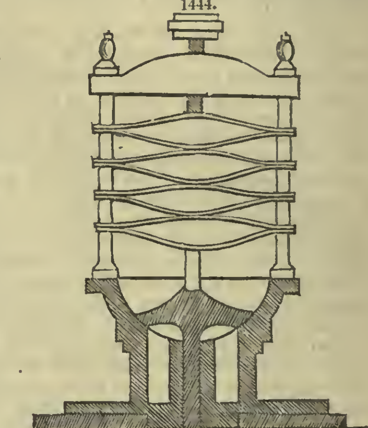
The admission of the steam from the boiler to the cylinders is regulated by a valve or regulator which is generally placed immediately above the internal fire-box, and is connected with two copper pipes, one conducting steam from the highest point of the dome down to it, and the other conducting the steam that has passed through it along the boiler to the upper part of the smoke-box. Regulators may be divided into two sorts, viz., those with sliding-valves and steam-ports, and those with conical valves and seats, of which the latter kind are the best. The former kind have for the most part hitherto consisted of a circular valve and face, with radial apertures, the valve resembling the outstretched wings of a butterfly, and being made to revolve on its central pivot, by connecting-links between its outer edges or by a central spindle. In some of Stephenson's engines with variable expansion geer, the regulator consists of a slide-valve covering a port on the top of the valve-chests. A rod passes from this valve through the smoke-box below the boiler, and by means of a lever parallel to the starting lever, is brought up to the engineer's reach. Cocks were at first used as regulators, but were given up, as they were found liable to stick fast. A gridiron slide-valve has been used by Stephenson, which consists of a perforated square plate moving upon a face with an equal number of holes. This plan of a valve with a small movement gives a large area of opening. In Bury's engines a sort of conical plug is used, which is withdrawn by turning the handle in front of the fire-box; a spiral groove of very large pitch is made in the valve-spindle, in which fits a pin fixed to the boiler, and by turning the spindle an end motion is given to it which either shuts or opens the steam passage according to the direction in which it is turned. The best regulator would probably be a valve of the equilibrium description, such as is used in the Cornish engines.

Safety-valves and fusible plugs.—The safety-valves are placed upon the dome, in Bury's and Stephenson's engines; but it has been found much better to place them on the cylindrical part of the boiler, because when an engine commences to prime, the water projected from the blast-pipe generally causes an

unusual generation of steam, which escapes at the safety-valve, and in its passage of course accumulates and lifts the surface-water and foam at whatever point of the boiler the safety-valves are situated; thus the farther they are placed from the steam-dome the better, as they will then diminish the evil of priming, which, if placed upon the steam-dome, they would only aggravate. Indeed, if the safety-valves are properly situated, an engineman has the great advantage of being able to check or stop the priming of the boiler on the instant, by causing his safety-valves to blow off strongly. It is requisite to place the safety-valves upon a tubular pillar, of such altitude as to prevent the escaping cloud of steam from obscuring the look-out of the engineman. Bury's 14-inch engine contains a pair of safety-valves of 2½ inches diameter, exclusive of the mitre; and Stephenson's 15-inch engine contains a pair of 4-inch diameter. The latter dimension is preferable, as large safety-valves are much less liable to adhere to their seats than small ones. Safety-valves require to be tested occasionally; and the best method consists in attaching the valve joint-pin to one end of an ordinary pair of scales, when the overbalancing weight at the reverse end will indicate the real pressure upon the valve, which exceeds the nominal pressure by the weight and friction of the lever, with its joints and spring balance, and the adhesion of the valve to its seat. To bring this adhesion to a minimum, it is a good plan to make the lip of the valve-seat somewhat flatter than a mitre, that is, at a less angle than 45° with the horizon: 30° answers very well.

The safety-valve is pressed down by means of a lever, and a screw at its extremity is attached to a spiral spring balance. To find the pressure per square inch, multiply the weight indicated on the scale, by the ratio of the two arms of the lever, and divide the product by the number of square inches in the area of the valve; but to save the trouble of calculation, the ratio of the arms of the lever is made so as to be expressed by the number which represents the area of the valve, so that the weight marked on the balance is the pressure per square inch upon the valve. Some allowance must be made for the weight of the valve itself, and part of that of the lever. It is expedient to put a stop upon the screw by which the lever is screwed down or the tension of the spring increased, so as to prevent the pressure from exceeding a safe amount. Lock-up valves, which were intended as a precaution against the recklessness or neglect of the engineer, have fallen into disfavor, as from such valves being inaccessible and seldom being required to act, they became fixed in their seats; but it is an easy thing to make a valve which can be raised, but cannot be forced down by the engineer, and such valves are in general use in steam vessels. In the engines of Cave, Hick, and Jackson, one of the valves is permanently loaded a little above the usual pressure, and enclosed in a chest; it is usually made with bent, flat, steel springs, pressing against one another, and guided by standards screwed to the valve-seat. One of these valves is shown by Fig. 1444.

1444.



A plug of lead is usually fixed in the furnace crown, which melts if the boiler becomes short of water, and gives notice of the danger. In some engines a cock is attached to the top of the steam-dome, against which a small disk of fusible metal is retained by a ring of brass bolted to the cock, and which is intended as an antidote to explosions. When the cock is opened, the steam has access to the under side of the fusible plate, which when melted is forced through the small hole in the retaining plate; and the engineer being thus warned of the undue pressure, can shut the cock and take measures to reduce the pressure. This, however, is altogether a futile expedient, for the steam would be too much cooled in passing through this cock and small pipe to melt the metal: and even if that defect were remedied, the objections still remain, as applying to all fusible plugs, and the danger is increased by leading the engineer to trust to a measure of safety that is inoperative in the hour of danger. Steam gages have not been applied hitherto to locomotives, on account of the inconvenient height of the column of mercury requisite to balance the steam. But it would be an easy thing to make a steam gage of moderate dimensions, by making the tube, whether straight or siphon, of glass, closed at the top, so that the mercury in its ascent would have to compress the air above it; and the graduations would be equal, or nearly so, if the tube were made taper.

Cylinders and valves.—The cylinders are made of cast-iron, about three-quarters of an inch thick, and should be of hard metal, so as to have but little tendency to wear oval from the weight and friction of the piston. The ends of the cylinder are made about one inch thick, and both ends are very generally made removable. At each end of the cylinder there is generally about half an inch of clearance. The valve is invariably of the three-ported description: it is made of brass, and is not pressed upon by the valve-casing, as it is necessary in the absence of cylinder escape-valves that the steam-valve should be capable of leaving the face to enable the steam or air shut within the cylinder to escape when the train is carried on by its momentum, and also to afford an escape for the water carried over by the steam when priming takes place. The operation of priming upon the cylinders and valves is very injurious, as the grit and sediment then carried over with the steam wears the pistons, cylinders, and valve faces very rapidly; so that if the water be sandy and the engine addicted to priming, the pistons and valves may be worn out and the cylinders require re-boring in the course of a few months.

The valve-casing is sometimes cast on the cylinder: the face of the cylinder on which the valve works is raised a little, so that any foreign matters deposited upon it may be pushed off to the less elevated parts by the valve. The area of the steam-ports is in some cases one-ninth, and in others one-twelfth

or one-thirteenth of the area of the cylinder; and the eduction one-sixth to one-eighth of the area of the cylinder,—proportions which allow at mean speeds of twenty-five to thirty miles per hour, a pressure little different from that of the steam in the steam pipes: for higher speeds the ports should be larger in proportion. The valve casing is covered with a door, which can be removed to inspect the valves or the cylinder face. Some valve casings have covers upon their front end as well as their top, which admits of the valve and valve bridle being more readily removed.

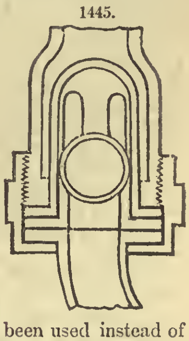
A cock is placed at each end of the cylinder to allow the water to be discharged which accumulates there from priming and condensation. The four cocks of the two cylinders are connected, so that by working a handle the whole are opened or shut at the same time. In Stephenson's engines with variable expansion, there is but one cock, which is on the bottom of the valve chest.

The valve lever is usually longer than the eccentric lever, to increase the travel of the valve. The pins of the eccentric lever wear quickly. Stephenson puts a ferule of brass on these pins, which being loose and acting as a roller, facilitates the throwing in and out of geer, and when worn can easily be replaced; so that there need be no material derangement of the motion of the valve from play in this situation. The starting lever travels between two iron segments, and can be fixed at the dead point or for the forward or backward motions. This is done by a small catch or bell crank jointed to the bottom of the handle at the end of the lever, and coming up by the side of the handle, but pressed out from it by a spring. The smaller arm of this bell crank is jointed to a bolt which shoots into notches made in one of the segments between which the lever moves. By pressing the bell crank against the handle of the lever, the bolt is withdrawn, and the lever may be shifted to any other point; when the spring being released, the bolt flies into the nearest notch.

The pistons which consist of a single ring and tongue piece, or of two single rings set one above the other so as to break joint, are preferable to those which consist of many pieces. In Stephenson's pistons the screws are liable to work slack and the springs to break. The piston-rods are made of steel, the diameter being from one-seventh to one-eighth of the diameter of the cylinder. They are tapered into the piston, and secured there with a cutter. The top of the piston-rod is secured by a cutter into a socket with jaws, through the holes of which a cross-head passes, which is embraced between the jaws by the small end of the connecting rod, while the ends of the cross-head move in guides. Between the piston-rod clutch and the guide blocks, the feed-pump rod joins the cross-head in some engines. The guides are formed of steel plates attached to the framing, between which work the guide blocks, fixed on the ends of the cross-head, and which have flanges bearing against the inner edges of the guides. Steel or brass guides are better than iron ones. Stephenson and Hawthorn attach their guides at one end to a cross-stay,—at the other to lugs upon the cylinder cover; and they are made stronger in the middle than at the ends. Stout guide-rods of steel encircled by stuffing-boxes on the ends of the cross-head would probably be found superior to any other arrangement. The stuffing-boxes might contain conical bushes cut spirally, in addition to the packing; and a ring cut spirally might be sprung upon the rod and fixed in advance of the stuffing-box with lateral play, to wipe the rod before entering the stuffing-box, and prevent it from being scratched by the adhesion of dust.

Feed apparatus.—The feed-pumps are made of brass, but the plungers are sometimes made of iron, and are generally attached to the piston-rod cross-head, though in Stephenson's engines they are worked by rods attached to eyes on the eccentric hoops. There is a ball valve between the pump and the tender, and two usually in the pipe leading from the pump to the boiler, besides a cock close to the boiler, by which the pump may be shut off from the boiler in the case of accident to the valves. The ball valves are guided by four branches which rise vertically and join at top in a hemispherical form, as shown in Fig. 1445. The shocks of the ball against this have in some cases broken it after a week's work, from the top of the cage having been made flat, and the branches not having had their junction at top properly filleted. These valve guards are attached in different ways to the pipes; when one occurs at the junction of two pieces of pipe it has a flange, which, along with the flanges of the pipes and that of the valve seat, are held together by a union joint. It is sometimes formed with a thread at the under end, and screwed into the pipe. The balls are cast hollow, to lessen the shock as well as to save metal: in some cases, where the feed-pump plunger has been attached to the cross-head, the piston-rod has been bent by the strain; and that must in all cases occur if the communication between the pump and boiler be closed when the engine is started, and there be no escape valve for the water. Spindle valves have in some cases been used instead of ball valves, but they are more subject to derangement. Slide valves might easily be applied, and would probably be found preferable to either of the other expedients. The pipes connecting the tender with the pumps should allow access to the valves and free motion to the engine and tender.

1445.



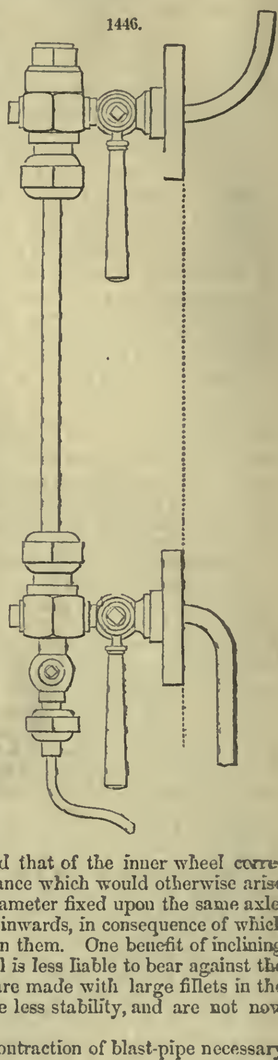
The feed-pipe of many engines enters the boiler near the bottom, and about the middle of its length. In Stephenson's the water is let in at the smoke-box end of the boiler, a little below the water level. By this means the heat is more effectually extracted from the escaping smoke; but the arrangement is of questionable applicability to engines of which the steam-dome and steam-pipe are at the smoke-box end, as in that case the entering cold water would condense the steam.

To ascertain the height of water in the boiler, gage-cocks and glass tubes are provided, as in the case of marine boilers. One of these glass gages is represented in Fig. 1446. The upward turn of pipe proceeding from the top of the tube in the interior of the boiler, is calculated to prevent the water from boiling down through the tube, as it sometimes will do if the boiler be too full. The downward turn of the tube at the lower end does not appear calculated to be of service. A small screw plug is placed on each socket opposite the cock to enable a wire to be introduced, to clear the cock, should it become choked. There are generally three gage-cocks attached to the boiler,—besides the glass tube,—the

lowest of which should always run water, and the highest should always blow steam. If the water oscillates inconveniently in the glass tube, the evil may be checked by partially closing the cocks.

Wheels.—The driving wheels are made large to increase the speed; the bearing wheels also are easier on the road when large. In freight engines the driving wheels are smaller than in passenger engines, and are generally coupled together. Wheels are made in various ways; they are frequently made with cast-iron naves, and with the spokes and rim of wrought-iron. The spokes are forged out of flat bars with T formed heads; these are arranged radially in the founder's mould, whilst the cast-iron centre is poured around them; the ends of the T heads are then welded together to constitute the periphery of the wheel or inner tire, and little wedge-form pieces are inserted where there is any deficiency of iron. In some cases the arms are hollow though of wrought-iron, the tire of wrought-iron, and the nave of cast-iron; and the spokes are turned where they are fitted into the nave, and are secured in their sockets by means of cutters. Hawthorn makes his wheels with cast-iron naves, and wrought-iron rims and arms, but instead of welding the arms together, he makes palms on their outer end, which are attached by rivets to the rim. These rivets, however, unless very carefully formed, are apt to work loose; and we think it would be an improvement if the palms were to be slightly indented into the rim, in cases in which the palms do not meet one another at the ends. When the rim is turned, it is ready for the tire, which is now often made of steel. The materials for wheel tires are first swaged separately, and then welded together under the heavy hammer at the steel works, after which they are bent to the circle, welded, and turned to certain gages. The tire is now heated to redness in a circular furnace; during the time it is getting hot, the iron wheel, previously turned to the right diameter, is bolted down upon a face-plate or surface; the tire expands with the heat, and when at a cherry-red, it is dropped over the wheel, for which it was previously too small, and it is also hastily bolted down to the surface plate; the whole load is quickly immersed by a swing crane into a tank of water about five feet deep, and hauled up and down until nearly cold; the tires are not afterwards tempered. It is not indispensable that the whole tire should be of steel, but a dovetail groove turned out of the tire at the place where it bears most on the rail, and fitted with a band of steel, which may be put in in pieces, is sometimes adopted, though at the risk of being thrown off in working. The steel, after being introduced, is well hammered, which expands it sideways, until it fills the dovetail groove, but it has sometimes come out. The tire is attached to the rim by rivets with countersunk heads, and the wheel is then fixed on its axle. The tire is turned somewhat conical, to facilitate the passage of the engine round curves—the diameter of the outer wheel being virtually increased by the centrifugal force, and that of the inner wheel correspondingly diminished, whereby the curve is passed without the resistance which would otherwise arise from the inequality of the spaces passed over by wheels of the same diameter fixed upon the same axle The rails, moreover, are not set quite upright, but are slightly inclined inwards, in consequence of which the wheels must either be conical or slightly dished, to bear fairly upon them. One benefit of inclining the rails in this way and coning the tires is, that the flange of the wheel is less liable to bear against the side of the rail, and with the same view the flanges of all the wheels are made with large fillets in the corners. Wheels have been tried loose upon the axle, but they have less stability, and are not now much used.

1446.



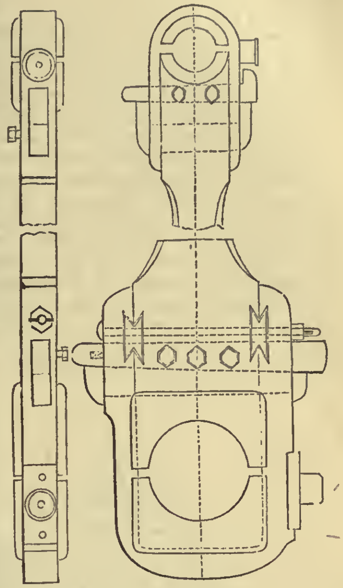
In all locomotives, there is a very material loss of power from the contraction of blast-pipe necessary to maintain the blast; at high speeds one half of the power of the engine is lost by the inadequate area of the steam passages, of which the greatest loss is that arising from the contraction of the blast-pipe. Tenders are now made larger to obviate the necessity of so many fuel and water stations. Tenders can be put on any number of wheels, so that inconvenience is not likely to arise from their size and weight.

Cranked axle.—The cranked axle is made of wrought-iron, with two cranks forged upon it, towards the middle of its length, at a distance from each other answerable to the distance between the cylinders; bosses are made on the axle for the wheels to be keyed upon, and there are bearings for the support of the framing. The axle is usually forged in two pieces, which are then welded together. Sometimes the pieces for the cranks are put on separately, but those so made are liable to give way. In engines with outside cylinders the axles are straight, the crank-pins being inserted in the naves of the wheels. The bearings to which the connecting-rods are attached are made with very large fillets in the corners, so as to strengthen the axle in that part, and to obviate side play in the connecting-rod. In engines which have been in use for some time, however, there is generally a good deal of end play in the bearings of the axles themselves, and this slackness contributes to make the oscillation of the engine more violent.

Connecting-rods.—It is very desirable that the length of the connecting-rod should remain invariable, in spite of the wear of the brasses, for there is a danger of the piston striking against the cover of the cylinder, if it be shortened, as the clearance is left as small as possible, in order to economize steam. In

some engines the strap encircling the crank-pin is fixed immovably to the connecting-rod by dovetailed keys, as shown in Fig. 1448, and a bolt passes through the keys, rod, and strap, to prevent the dovetail keys from working out. The brass is tightened by a gib and cutter, which is kept from working loose by three pinching screws, and a cross-pin or cutter through the point. The effect of this arrangement is to lengthen the rod, but at the cross-head end of the rod the elongation is neutralized, by making the strap loose, so that in tightening the brass the rod is shortened by an amount equal to its elongation at the crank-pin end. The tightening here is also effected by a gib and cutter, which is kept from working loose by two pinching screws pressing on the side of the cutter. Both journals of the connecting-rod are furnished with oil-cups, having a small tube in the centre, with siphon wicks. The connecting-rod, represented in Figs. 1448, 1447, is a thick flat bar, with its edges rounded. Stephenson's connecting-rod is made at the crank end; a strap of round iron passes over both brasses, and is attached to the T end of the connecting-rod by means of nuts upon the ends of the bent iron, which is made thickest in the middle, to resist the strain. This plan has the defect of shortening the connecting-rod when the brasses are screwed up, and the brasses require to be very strong and heavy. Hawthorn's connecting-rod has a strap at each end, tightened by a gib and cutter; but, to obviate the tendency to shorten the rod, the piston-rod end is furnished with a cutter for tightening the brass outwards. The point of the cutter is screwed, and goes through a lug attached to the gib, and is tightened by a nut. It would be preferable to attach the lug to the cutter and the screw to the gib, as the projection of the screw, when the cutter is far in, would not then be so great. In the engines on the Rouen Railway the piston-rod end of the connecting-rod has neither strap nor brass, but simply embraces the cross-head, while the crank end is hollowed out to admit brasses, which are tightened by a gib and cutter. The length of the connecting-rod varies from four times the length of the crank to seven times. The long connecting-rod has the advantage of diminishing the friction upon the slides.

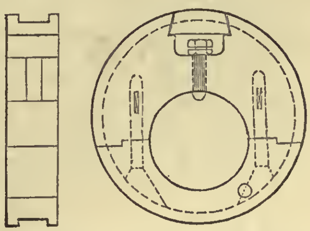
1448. 1447.



Eccentrics and eccentric-rod.—The eccentrics are made of cast-iron; and when set on the axle between the cranks, they are put on in two pieces held together by bolts, as shown in Figs. 1449, 1450: but in straight-axle engines they are cast in a piece, and are secured on the shaft by means of a key. The eccentric, when in two pieces, is retained at its proper angle on the shaft by a pinching screw, which is provided with a jam-nut to prevent it from working loose. A piece is left out of the eccentric in casting it, to allow of the screw being inserted, and the void is afterwards filled by inserting a dovetailed piece of metal. Stephenson and Hawthorn leave holes in their eccentrics on each side of the central arm, and they apply pinching screws in each of these holes. The screws sometimes slacken and allow the eccentric to shift, unless they are provided with jam-nuts. In the Rouen engines with straight axles, the four eccentrics are cast in one piece.

Eccentric straps are best made of wrought-iron, as inconvenience arises from the frequent breakage of brass ones. When made of malleable iron, one-half of the strap is forged with the rod, the other half being secured to it by bolts, nuts, and jam-nuts. Pieces of brass are in some cases pinned within the malleable iron hoop, but it appears to be preferable to put brasses within the strap to encircle the eccentric, as in the case of any other bearing. When brass straps are used, the lugs have generally nuts on both sides, so that the length of the eccentric-rod may be adjusted; but it is better for the lugs of the hoops to abut against the necks of the screws, and if any adjustment is necessary from the wear of the straps, washers can be interposed. In some engines the adjustment is effected by screwing the valve-rod, and the cross-head through which it passes has a nut on either side of it by which its position upon the valve-rod is determined. The forks of the eccentric-rod are steel. The length of the eccentric-rod is the distance between the centre of the crank axle and the centre of the valve-shaft.

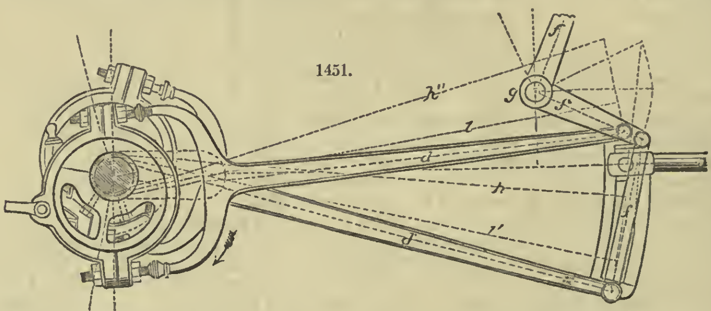
1450. 1449.



Valve motions.—In locomotives the eccentrics are now always fixed upon the axle, and two are used, one for the forward, the other for the backward motion: the loose pulleys have been given up on account of their liability to get out of order from the shocks to which they were subjected by sudden change of direction when worked at a quick speed. The arrangement whereby the motion of the eccentric is transmitted to the valve, is either direct or indirect. In cases of indirect attachment the motion is given through the intervention of levers, and there is some variety in the arrangements by which the reversing is accomplished. Alcard and Buddicome use a pair of eccentrics at the end of the axle, which is straight; the reversing shaft is placed below the level of the piston-rod, and to a lever keyed upon it are attached links of unequal length, connected at their upper extremities with the ends of the eccentric-rods, one of which is above and one below the studs on the lever of the valve-shaft, so that the upper eccentric-rod, being in geer, gives the forward motion, and the lower gives the backward motion. In other engines, forks are situated above and below the stud of the eccentric levers; the forward eccentric-rod is lifted up out of geer by a link depending from the lever on the reversing shaft,

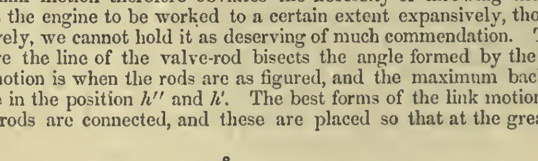
and by the same movement the backing eccentric is lifted into geer by a longer link connecting it to a lever, not upon the reversing shaft, but upon a shaft below it. Stephenson and Hawthorn have both used a similar arrangement, but admitting of the eccentric-rods being both under the studs of the lever on the valve-shaft, so that there is no danger, in the event of a disengaged rod falling down, or of any part of the geering being bent or twisted by both rods being in geer at the same time. The motion of the eccentrics is now frequently transmitted directly to the valves. In Pauwel's arrangement of valve geering, the valve works on the side of the cylinder, and the valve-rod is prolonged in the form of a deep flat blade of a lozenge section, on each side of which a stud is fixed,—one being intended for the notch of the forward eccentric-rod, and the other for that of the reversing eccentric. Above them is fixed the reversing shaft, from a lever on which depend two links of unequal length, which are jointed to the ends of the eccentric-rods. By working this lever up or down, the eccentric-rods will be alternately engaged and disengaged, and will communicate their respective motions to the valve; or if the lever be kept in its mid position, both eccentrics will be out of geer, and the valve of course will remain stationary. Pauwel's engines are difficult to work, and are subject to shocks from going suddenly into geer: this arises from the whole weight of levers and rods being on the front of the reversing shaft, but the evil might be remedied by attaching a counterbalance to the shaft. Valves situated upon the sides of the cylinders are in many cases more easily connected with the eccentric, but they require springs to keep them up to the face, so that it appears preferable to make the faces of the two cylinders inclined to one another rather than upright, if valves on the sides of the cylinders are preferred. Stephenson's link motion is the most elegant, and one of the most eligible modes of connecting the valve with the eccentric yet introduced. The nature of this arrangement will be made plain by a reference to Fig. 1451, where e is the valve-rod which is attached by a pin to an open curved link connected at the one

1451.



end with the driving eccentric-rod d, and at the other with the backing eccentric-rod d'. The link with the eccentric rods is capable of being moved up or down by the rod f and bell crank f'', situated on the shaft g, while the valve-rod remains in the same horizontal plane. It is very clear that each end of the link must acquire the motion of the eccentric-rod in connection with it, whatever course the central part of the link may pursue, and the valve-rod will partake most of the motion of the eccentric-rod that is nearest to it. When the link is lowered down, the valve-rod will acquire the motion of the upper eccentric-rod, which is that proper for going ahead; when raised up, the valve-rod will acquire the motion of the reversing eccentric, while in the central position the valve-rod will have no motion, or almost none. The link motion therefore obviates the necessity of throwing the eccentric-rod out of geer; it also enables the engine to be worked to a certain extent expansively, though as a contrivance for working expansively, we cannot hold it as deserving of much commendation. The dead point of the link motion is where the line of the valve-rod bisects the angle formed by the eccentric rods. The maximum forward motion is when the rods are as figured, and the maximum backward motion when the rods d and d' are in the position h'' and h'. The best forms of the link motions have side studs, to which the eccentric-rods are connected, and these are placed so that at the greatest throw, whether

1452.



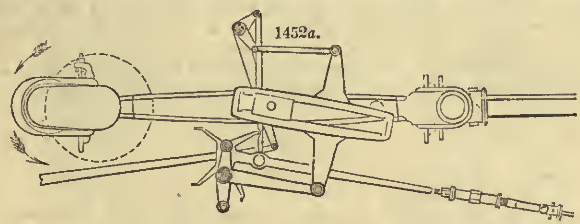
backward or forward, the valve-rod and eccentric-rod are in the same straight line, and the valve receives the full throw of the eccentric. A counter-weight is also attached to the shaft to balance the weight of the link and rods. The second eccentric and eccentric-rod of the link motion might, it appears to us, be beneficially dispensed with by placing the shaft g in the plane of the valve-rod, and attaching a pin to the centre of the link, which would work in the eye of the horizontal arm of the lever f. This lever would in such case require to be made much stronger than at present, as it would have to withstand the thrust of the eccentric, and the link would then virtually be a double-ended lever with a movable centre. Where more convenient, the pin in the centre of the link might be moved in vertical or curved guides, instead of being attached to the lever f. The act of raising the link, and with it the

eccentric-rod, would in effect alter the position of the eccentric on the shaft, and if the eccentric-rod were properly proportioned in length, would make the lead right on the reversing side.

The movement for working the valves is in some cases derived from the connecting-rod, as in the arrangement known as Melling's motion, represented in Fig. 1452, where the valve-rod is attached by suitable connections to a pin in the connecting-rod.

A somewhat similar mode of working the valve has been employed by Hawthorn, of Newcastle, which admits of expansive action, and which is represented in Fig. 1452*a*. The pin in the connecting-rod works in a link, to which arms are attached at right angles. The extremity of the lower of these arms is connected by a link and lever to a shaft, which is worked by the reversing handle, while the upper arm is attached to a lever upon the valve-shaft. Upon this shaft there is a double-ended lever, with either end of which a rod, in communication with the valve, geers, according as a forward or reverse motion is wanted. This valve-link is connected by a link with the starting-shaft. The central slot in the link permits the free end movement of the pin on the connecting-rod, while the lateral movement is communicated to the link, and made available for working the valve levers. To reverse the engine, the inclination of the link must be altered, and the fork in geer must be changed to the other end of the lever, which is done by the same handle: the lead is regulated by the degree of inclination of the parallelogram, which might be changed by lengthening the lever on the reversing-shaft connected with the lower arm of the link, or by shifting it round on the shaft so as to throw the lower arm towards the cylinder. There is much complication in this arrangement; the parts, too, require to be large, and the plan has not been received with much favor, although good results have been obtained.

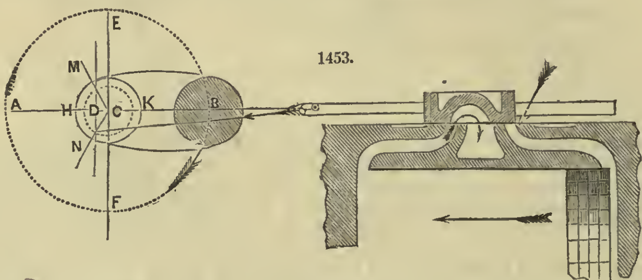
1452*a*.



Variable expansive action has recently been extensively introduced in locomotives, and the whole of the various expedients for its accomplishment operate either by altering the travel of the valve, or by the introduction of superposed valves. The first mode is that adopted by Stephenson and Cabrey, and the second is principally used by Mayer and Gonzenbach. In the first the effect is to uncover the steam ports less, and re-shut them sooner; to hurry the eduction, and to compress the steam shut within the cylinder: from the early closing of the eduction, the advantages due to expansion are partly sacrificed, for the steam escapes before it has done all its work, and power is lost in the compression of vapor. The second class of expansion contrivances is not chargeable with these defects. It admits of the steam being cut off at any part of the stroke, without any derangement of the valve motion, but there is greater complication in the apparatus. In the class with variable throw, the cutting off is the result of a virtual contraction of the ports, which wire-draws the steam, increasing the speed of the entering steam, and making the pressure in the cylinder less than in the passages. In Cabrey's expansion geer, the fault is, that for certain degrees of travel, and when there is much cover on the valve, it may happen that instead of opening the port before the end of the stroke, the valve may not have uncovered the steam port when the piston is about to begin the return stroke. This evil results from the invariable position of the eccentrics on the shaft, and the immobility of the centre of the valve lever. Stephenson gets rid of the defects of Cabrey's system in regard to changing the lead of the eccentric, by rendering movable the centre of oscillation of the valve lever, as the link may be considered, whereby he virtually turns round the eccentric on the axle. Mayer's geer has given very good results, and is free from the defects of Cabrey's and Stephenson's. Whatever be the degree of expansion, it presents the same area of steam port; the eduction is not unduly hurried, the linear lead is unvarying, and the compression of the steam before the piston is but small, and is not liable to increase. The wheel and chain geering, however, used in working it, are very troublesome, and liable to get out of order, and the valves have a great deal of friction. Gonzenbach's has less friction than Mayer's, and gives equally good results.

How to set the valves of locomotives.—When the cylinder is horizontal the crank is horizontal at the ends of the stroke; but it is not vertical when the piston is at the middle of its stroke, owing to the deviation from parallelism introduced from the connecting-rod being compelled to move at one of its extremities in a straight line. When the piston is at the end of the bottom stroke, and is gradually advanced towards the middle of the stroke, the end of the connecting-rod is carried round by the crank in a curve opposed to that which it would naturally describe round the cross-head as centre; but when the piston has approached the end of the top stroke, the curvature of the path in which the end of the connecting-rod is moved by the crank is in the same direction as that of the circle which it would describe round the cross-head, and these curves would coincide if the connecting-rod were equal in length to the crank: it will be easily seen, therefore, that at the top stroke the piston-rod requires but a small movement to enable the end of the connecting-rod to traverse a large portion of the circle of the crank, while at the bottom stroke the piston has to travel farther to allow of an equal arc being described by the crank. From these considerations it follows, that the motion of the crank being nearly uniform, there must be considerable inequalities in the speed of the piston; and more than a half circle will be described by the crank during the top half of the stroke, and less than a half circle in the bottom half of the stroke. The length of the connecting-rod is the distance from the cross-head at half stroke to the

centre of the shaft; and it is clear, therefore, that at mid-stroke the crank cannot be vertical. The motion of the valve partakes of the same species of irregularity; but as the eccentric-rod is much longer in proportion to the radius of the eccentric than the connecting-rod, that inequality only may be noted which arises from the relation between the circumference of a circle and its diameter. The irregularity arising from the angle of the connecting-rod also affects the valve, but not to an injurious extent in ordinary cases. In Fig. 1453 we have shown the direct connection, as used in some of Stephenson's locomotives, A E B F representing the crank circle, and the inner circle that of the eccentric. Supposing, now, that the total length of the valve face were equal to the distance between the extreme edges of the steam ports, the valve would be without *lap;* and leaving the question of *lead* out of consideration for the present, that is, supposing that the steam were admitted exactly at the ends of the stroke, the eccentric would be fastened upon the shaft at right angles to the crank; in other words, the small crank which constitutes the eccentric would be at right angles to the large crank, which is attached to the piston-rod. In this way the valve would be in the middle of its stroke when the piston was at either end of its stroke, so as to close both the steam and eduction passages, and to be ready with the slightest possible advance, to open both for the return stroke of the piston. It has been found advantageous, however, to make the valve face longer than the distance between the extreme edges of the steam ports, so that when it is in the middle of its stroke, it projects or overlaps the ports at both ends; and hence it requires to move through a space equal to the overlap before it is in a condition to open the steam port for the return stroke of the piston. To effect this, it is only necessary to move the eccentric forward in its path, until, at the end of the stroke of the piston, the valve is on the edge of the steam port, ready, as before, upon the slightest farther advance, to admit the steam to the cylinder. Now, as the valve is thus required to move through a part of its travel or throw equal to the overlap at each end, and as the throw is equal to the diameter of the circle which the eccentric describes, it follows that, to give the requisite advance, that distance must be measured upon the diameter of the circle, and the corresponding position of the centre of the eccentric is that of which we are in search.

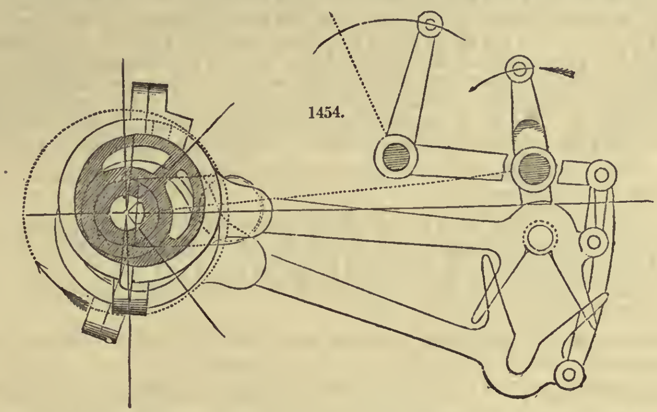


1453.

On the remote side of the centre of the crank-shaft, and on the line of centres, mark off D C, the amount of overlap at each end of the valve, and draw a line parallel to E F, the vertical centre line of the crank-shaft; the arc of the eccentric circle intercepted between these parallel lines is that through which the eccentric must move, in order to draw the valve through a portion of its stroke equal to the overlap D C; and the point in which the line intersects the circle of the eccentric is, therefore, the position which the centre of the eccentric should occupy, when the piston is at the end of its down-stroke, and on the very point of beginning its up-stroke. In practice, however, the valve is not so set as to open simultaneously with the commencement of the stroke of the piston, but is set so that the steam commences to flow into the cylinder a very little before the beginning of the stroke; and hence, when the piston actually commences its stroke, the valve has already partially opened the port. To make this adjustment, an additional advance must be given to the valve, and of course in the same direction; and the amount of *lead*, or opening, which the port has at the commencement of the stroke of the piston, must be added to the *lap*, their sum from C to D being treated the same in every respect as if the whole were *lap;* and so, for the sake of brevity, we may treat it.

Let us suppose now that it was required to find the length that the eccentric-rod should be:—Place the crank horizontal, so that it may have the piston at the bottom of its stroke; bring round the eccentric to the corresponding position which we find it should occupy, and measure the distance from that point to the centre of the joint by which the eccentric-rod is to be attached to the valve-rod; this will be the length of the eccentric-rod. When the length of the eccentric-rod is known, either the valve or eccentric may be put in its proper place, if one of them be already set: thus, if the valve be set, as in the drawing, and the eccentric-rod connected also with the eccentric, it will bring the latter into its place, where it may be fixed; but if the valve could not be conveniently set, it would then be necessary to take the following method, which requires the knowledge of the amount of lap, and the length of the eccentric-rod. Find, as before, the position of the eccentric, attach the rod, and the valve must come into connection in the proper position. In practice, the most convenient method of finding the position of the eccentric with a given lap is to draw a circle, such as H K, representing the crank-shaft, upon a board or a piece of sheet-iron, and another equal to the circle of the eccentric, and draw two diameters perpendicular to each other; mark off from the centre of the crank-shaft, and upon one diameter, the amount of lap C D; through this point draw a line parallel to E F, the other diameter; the points in which this line cuts the circle of the eccentric are the positions of the forward and backward eccentrics. Through these points, and from the centre of the crank-shaft, draw lines C M, C N, which will intersect the circumference of the crank-shaft; upon this circumference measure with a pair of compasses the chord of the arc intercepted between either point of intersection and that of the vertical diameter E F,

and the lines of diameters being first drawn upon the shaft itself, then, by transferring with the compasses the distance found upon the diagram, the proper position of the eccentric at the end of the stroke of the piston is at once determined; and this being marked upon the shaft, the eccentric can at any time be set, by bringing it round to that mark. Before leaving this figure we may remark, that as the valve in Stephenson's locomotives of this kind is on the side of the cylinder, the cylinder face should be towards us in the drawing. As this arrangement, however, would have afforded a less easy explanation, we have adopted the present one. It will also be observed that the crank-shaft and cylinder are too close, and are not in a line with each other; but this, while it could not be easily avoided, is at the same time of no importance in considering the respective motions of the piston and valve, crank and eccentric, which are shown in their true relative positions. The crank is upon the centre, and the piston, consequently, at the end of the bottom stroke; the eccentric and valve being put in advance of the piston by the lap, have shut off the steam before the end of the stroke, and have also opened the eduction in readiness for the up-stroke; whereas, without lap, the valve would shut off the steam at one end and open the eduction at the other, simultaneously with the termination of the stroke of the piston.


1454.

In Fig. 1454 we have a different kind of valve geering, there being levers, which reverse the direction of the motion; that is, while the eccentric-rod and lever are moving in one direction, the valve-rod and lever, being on the opposite side of the weigh-bar shaft, are moving in the opposite direction. In the former case there were no levers, and therefore no reversal of the motion. Hence, in order to give the valve the same motion as before, in relation to the crank, it is necessary to throw the eccentric to the opposite side of the crank-shaft, so that its motion may be in the reverse direction, to compensate for the reversing action of the levers. For whereas, when upon one side of the shaft they caused the valve to move in the same direction as themselves by means of the eccentric-rods, now that the levers are introduced, the eccentrics must themselves move in an opposite direction, to give the valves the same motion as heretofore. And this can only be done by putting the eccentrics on the opposite side of the crank centre, round which they move, and, of course, in an opposite direction.

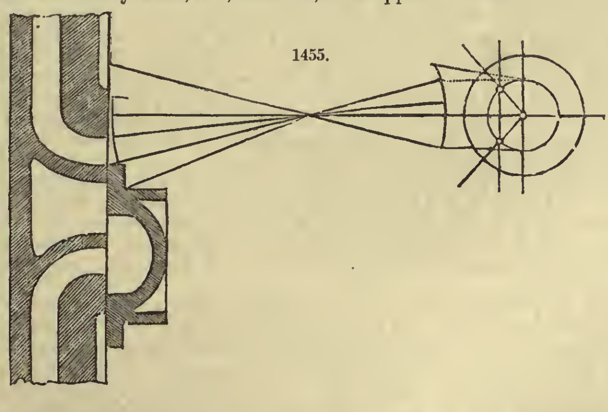

1455.

Fig. 1455 is intended to illustrate the valve connection of the common locomotive, in which the motion of the eccentric is communicated through levers to the valve, and generally with an increase of throw. In this figure we have the cylinder face, with the valve upon it, at one end of its travel. Measure off the length of the valve throw, from the end of the valve face, in the direction of its travel. The throw of the valve may best be found by adding the lap to the breadth of the steam-port, and doubling their sum. If there were no levers intervening between the valve and eccentric, the line thus measured, which is the throw of the valve, would be the diameter also of the circle described by the centre of the eccentric pulley; but the use of levers interferes with this proportion unless the levers be

made of equal length. The effect of levers of unequal length, in making a proportional inequality between the throw of the valve and of the eccentric, will be readily seen by reference to a diagram. From the centre A of the diameter, representing the throw of the valve, draw a line perpendicular to the valve face; and from the same point measure off, upon that line, the length of the lever A B, which is to be attached to the valve-rod, and which, for distinction, we shall call the valve lever. From the point B thus found as a centre with the radius B A, describe a portion of a circle intersecting perpendiculars drawn from C and D, the extremities of the line which represents the throw of the valve; from those points in the circumference of the circle produce lines through the centre B. On either side of the centre line A E, and at a distance from it equal to the radius of the eccentric, draw a parallel line. From B as a centre, with the distance from the centre B to the points H K,—in which the parallels intersect the produced lines of the lever, as radius,—describe an arc of a circle; the radius of this circle is the length which the eccentric lever must be, in order to give the requisite throw to the valve. It will be evident from the inspection of this diagram, that if it be desired to give a smaller throw to the valve than that of the eccentric, it is necessary to make the valve lever shorter than the eccentric lever; and if it were desired to make the valve throw greater than the eccentric throw, it is indispensable that the valve lever should be made proportionally longer than the eccentric lever. If, for example, the throw of the valve is to be made twice the throw of the eccentric, then this can only be accomplished by making the valve lever twice the length of the eccentric lever. Hence the relations between these quantities are expressed by simple proportion; and any three being given, we can readily find the remaining one. For the sake of clearness, we shall state the various forms which the proportion will assume.

First.—Given the throw of the valve, the throw of the eccentric, and the length of the lever attached to the valve-rod, to find the length of the eccentric lever; we have then the proportion:—

Rule.—As the throw of the valve is to the throw of the eccentric, so is the length of the valve lever to the length of the eccentric lever.

If we represent the throw of the valve by T, that of the eccentric by t, the valve lever by L, and the eccentric lever by l, we will have the proportion in a condensed algebraic form, thus,—$T : t :: L : l$; or taking the actual dimensions in inches of the engine before us, $4{\cdot}5 : 3 :: 9 : 6$.

Secondly.—Given the throw of the valve, the throw of the eccentric, and the length of the eccentric lever, to find the length of the valve lever. Then,

Rule.—As the throw of the eccentric is to the throw of the valve, so is the length of the eccentric lever to the length of the valve lever;

Or, algebraically, $t : T :: l : L$; or, as before, in actual dimensions, $3 : 4{\cdot}5 :: 6 : 9$.

Thirdly.—Given the throw of the valve and the lengths of the levers, to find the throw of the eccentric.

Rule.—As the valve lever is to the eccentric lever, so is the valve throw to the eccentric throw;

Or thus, $L : l :: T : t$; or, $9 : 6 :: 4{\cdot}5 : 3$.

Fourthly.—Given the eccentric lever, the valve lever, and the eccentric throw, to find the valve throw.

Rule.—As the eccentric lever is to the valve lever, so is the eccentric throw to the valve throw;

Or, $l : L :: t : T$; or, $6 : 9 :: 3 : 4{\cdot}5$.

We formerly explained how the reversing action of the levers rendered it necessary to set the eccentric on that side of the crank-shaft centre nearest to the cylinder; whereas, in the case of the direct valve connection, it was set on the side remote from the cylinder. Having now found the means of ascertaining the lengths of the levers to be employed with a given throw of valve and eccentric, the next step necessary is to determine the true position of the eccentric upon the shaft, in reference to the crank.

Place the crank-pin in the dead point nearest the cylinder; that is, place the centres of the crank-shaft and crank-pin in a line with the centre line of the piston-rod. Upon this line of centres A G, raise a perpendicular L M, through the point F. From F draw a circle, the diameter of which is equal to the throw of the eccentric, and another equal to the cranked axle. If the levers are equal, mark off from F, upon the line of centres and on the cylinder side, the amount of lap, and draw a line parallel to L M, cutting the eccentric circle in the points N O. From F draw lines through N and O to the circumference of the cranked axle. The points N and O are the positions of the centres of the eccentric pulleys for the forward and backward geer, only one of which is necessary for going one way. In practice it is convenient to make marks at P R, as the points N and O are inaccessible. If there were no lap upon the valve, there would be nothing to set off from the centre line L M, and therefore that line would give the positions of the eccentrics.

The intersections of the perpendicular A G would give the positions of the eccentrics on the shaft if the connecting-rod were infinitely long; but inasmuch as the shortness of the connecting-rod introduces irregularity, the true position of the crank at the middle of the stroke of the piston must be taken.

If the lengths of the levers be unequal, the throws of the eccentric and valve will also be unequal; and if the valve lever be the longer, as in the case we have taken, the eccentric throw is less than the valve throw in the same proportion as the eccentric lever is less than the valve lever; and therefore, since the eccentric throw is thus less than the valve throw, by reason of the levers, it follows that the lap, which we set off from F, and which is part of the valve throw, must also be diminished in the same proportion as the whole throw, in order to set off the proper quantity from F. The simplest way of accomplishing this is, by marking off the lap from the line of centres, Fig. 1455, at the point A, at the same end as we formerly marked off half the valve throw. This distance will be from A to the edge of the port, that being the overlap; then from the edge of the port draw a parallel to A G; and from the point in which this parallel cuts the arc of the longer lever, draw a line through the centre B, and

produce it till it cuts the arc K H; the perpendicular from this point to the line E A is the reduced amount of lap, which is to be set off from the point F.

Another useful problem is the method of finding the length of the eccentric-rod, the positions of the crank-shaft, and the weigh-bar shaft, and the length of the eccentric lever being given. From the centre of the weigh-bar shaft, with the length of the eccentric lever as radius, describe an arc; draw a tangent from this to the centre of the crank-shaft; from the centre of the weigh-bar shaft drop a perpendicular to the tangential line; the distance from the point of intersection to the centre of the crank-shaft is the length of the eccentric-rod, and the perpendicular is the line of the eccentric lever, when the valve lever is perpendicular to the line of the valve-rod: this gives, therefore, the positions in which these levers must be keyed upon the weigh-bar shaft.

In Fig. 1455 the mid-line of the eccentric-rod was the same as the line of the piston-rod; but in Fig. 1454 it is thrown down below that of the piston-rod, forming an angle with it, the vertex of which is the centre of the crank-shaft. In this case the centres of the eccentric pulleys must, consequently, be moved downwards as many degrees as the central line. In order to facilitate this adjustment, we may briefly explain, that every circle is supposed to have its circumference divided into 360 equal parts, called degrees; and if two diameters be drawn in it at right angles to each other, they will divide the circumference into four equal parts, each of which contains 90 degrees. This, therefore, is the means by which the angle is measured; nor will it matter, although the circle be of any size whatever, for it is still equally divided by the two diameters. Hence, if the number of degrees contained in the angle which the mid-line of the eccentric-rod makes with the line of the piston-rod, be measured upon any circle described from the centre of the crank-shaft, and the angle be laid down upon a board, and if from the vertex of the angle a circle be described equal to the diameter of the crank-shaft, the chord of the arc of this circle intercepted between the lines containing the angle, is the distance to be transferred upon the crank-shaft, and through which the eccentric pulley must be moved round, in order to compensate for the obliquity of the eccentric-rod. In the example, Fig. 1454, the mid-line of the eccentric-rod, when in geer, lies at an angle of five degrees with the line of the piston-rod; and in all such cases this line is to be taken when reference is made to the valve motion; and the piston-rod line is to be taken when reference is made to the motion of the piston. In the case of Fig. 1455, these lines were made to coincide, for the sake of simplicity.

Miscellaneous remarks respecting locomotives.—The tractive force requisite for drawing carriages over well-formed and level common roads is about 1-36 of the load, at low speeds. On railways, the tractive force has generally been rated at about 1-300 of the load, or 7½ pounds per ton, at low speeds; but in well-formed railways the tractive force is probably less than this, to keep the train moving slowly. The resistance of railway trains, however, increases rapidly with the speed, on account of the resistance of the atmosphere; and the resistance occasioned by the atmosphere may be taken at 15 pounds per ton, with an ordinary passenger train moving at the rate of 30 miles an hour. The friction of the engine and the resistance of the rails vary simply as the velocity, if the power of the engine remains the same; but the resistance of the atmosphere varies as the square of the velocity, and the power requisite for overcoming that resistance as the cube of the velocity: so that by doubling the speed of a train, by diminishing the load without increasing the power, the friction is doubled, the atmospheric resistance is made four times greater than before, and the power requisite to overcome that resistance eight times greater. This shows the extravagance of high speeds, even if the power were as economically produced at high speeds, which is by no means the case. In moderately light trains upwards of 50 per cent. of the power is expended in overcoming atmospheric resistance, in speeds of about 35 miles per hour; and the loss will be greater if the trains be very light, and present a large frontage.

We have already stated that in low-pressure condensing engines the evaporation of one cubic foot of water from the boiler may be taken to represent a horse power. In high-pressure engines, working without expansion, the mechanical efficacy of a cubic foot of water raised into steam will be somewhat less, on account of the resistance to the motion of the piston, occasioned by the pressure of the atmosphere; but in locomotive-engines, where the working pressure is very high, the resistance due to the pressure of the atmosphere becomes relatively nearly as small as the resistance due to the rare vapor within the condenser of a condensing-engine; and it will not, therefore, be a material deviation from the truth if, in locomotive-engines, working without priming, we reckon a cubic foot of water evaporated per hour as equivalent to a horse power. An engine evaporating 200 cubic feet of water per hour, and therefore exerting about 200-horse power, draws about 110 tons at thirty miles an hour; but if there were no loss from the resistance of the atmosphere, or of the blast-pipe, and no increased friction upon the engine from the increased power requisite for high speeds, the tractive force, if taken at 8 pounds per ton, would only require to be 70·4-horse power for $110 \times 8 \times 2640$, the number of feet travelled per minute at 30 miles an hour, $\div 33000 = 70{\cdot}4$-horse power. The friction of the train, however, at 30 miles an hour, including that of an engine of 200-horse power, cannot be taken at much less than 10 pounds per ton; for the friction of an engine increases with the power exerted, which determines the pressure upon its moving parts; and the friction of the carriages is also increased at high speeds, in consequence of the draw-bars being attached below the centre of effort of the frontage exposed to the wind, whereby the carriages are pressed down more firmly on the rails. If the traction be taken at 10 pounds per ton, then the power requisite for propulsion of a train, setting aside the resistance of the atmosphere, will be about 90-horse power, and the remaining 110-horse power is absorbed in overcoming the resistance of the atmosphere and of the blast-pipe. If the speed be increased from 30 to 60 miles an hour, about 200-horse power will be required for overcoming the friction of the train, and 880-horse power will be required to overcome the atmospheric resistance; making 1,080-horse power, which will be necessary to propel a train of 110 tons at 60 miles an hour. The evaporation of a locomotive boiler is greatest when the speed is at its maximum, as the blast-pipe then produces its greatest effect; and the power of the engine varies nearly as the rate of evaporation, provided the blast-pipe be not unduly contracted. At ordinary railway speeds the power of the boiler is seven or eight times greater than it

would be without the blast, though, indeed, such a comparison hardly holds, as without the blast the fire of a locomotive boiler would not draw at all. At a speed of 20 miles an hour, a locomotive boiler boils off from 10 pounds to 14 pounds of water per square foot of heating-surface, and the rate of evaporation varies nearly as the $\sqrt{}$ of the speed.

The adhesion of the wheels upon the rails is about one-fifth of the weight when the rails are clean, and either perfectly wet or perfectly dry; but when the rails are half wet or greasy, the adhesion is not more than one-tenth or one-twelfth of the weight. The weight of locomotive engines varies from 15 to 20 tons. A powerful locomotive engine and tender, such as is suitable for high speeds, will weigh about 25 tons. The consumption of power by the locomotive itself is very great at high speeds, chiefly in consequence of the resistance occasioned by the blast-pipe to the free escape of the steam. Mr. Stephenson considers that, at ordinary railway speeds, a locomotive engine will absorb as much power as 15 loaded carriages, weighing 60 tons; so that in a train of 15 carriages, half the power is consumed by the engine. These determinations, however, are all very indefinite, and experiments are yet wanting to show the power produced and consumed by locomotives under different circumstances. Locomotive engines in England cost from $9,000 to $11,000 each. They run, on an average, about 130 miles a day, at a cost for repairs of about 5 cents per mile; and the cost of locomotive power, including repairs, wages, oil, and tallow, and coke, may be taken at 12 cents per mile, on economically managed railways. This does not include a sinking fund for the renewal of engines which may be worn out, and which may be taken at 10 per cent. on the original cost of the locomotives. On second class railways the expense of locomotives, and workshops, and tools for repairing them, may be set down at $10,000 per mile.

Economy of fuel in locomotives is materially promoted by working expansively; but all attempts at economizing fuel in locomotives should begin with an increase in the area of the fire-grate, so that the power of the engine may not suffer so large a diminution by the creation of the necessary draft.

Every locomotive engine should be furnished with efficient expansion apparatus, of some kind or other; as, setting aside the economy of fuel accomplishable by expansion, it is clear that expansion acts beneficially by diminishing the weight of the boiler, which may be made smaller at every increase of the efficiency of the steam. When the draft is strong, a great loss of effect is caused by opening the furnace door, from the refrigeration due to the large volume of air admitted; and it would be a material improvement if the furnace could be fed by some such mechanism as the revolving grate. The use of sediment-collectors in locomotive boilers also appears expedient, as, if judiciously applied, they will effectually prevent the formation of scale upon the tubes, and will also operate as an antidote to priming in many cases. The form of collector best adapted for a locomotive boiler, will depend in a great measure upon the peculiar structure of the boiler; but generally any form will answer which communicates with the water level, and contains water within it in a tranquil state. The V-shaped cuts for establishing the communication between the exterior and interior of the vessel, have been found preferable to holes of any other form; for a subsiding particle, so soon as it falls in a slight degree, gets behind the case of the collecting vessel, and cannot afterwards escape.

Details of the engines of steam-frigate Dragon.—Fig. 1456 represents the paddle and intermediate shafts from the centre line of the vessel to the outer bearing. In this figure are introduced a section of one of the cranks and of the cam for working the expansion valve.

Fig. 1457 is a sectional view (taken through the centre of the valve face) of the cylinder and piston, with the piston-rod and cross-head.

Fig. 1458 shows a plan and sections of the elastic packing-ring at the middle and ends.

Fig. 1459 is a sectional view of the steam-pipe, showing the expansion and throttle valves.

Fig. 1460 represents a vertical section of the expansion-valve detached.

Fig. 1461 is a transverse section of the air-pump and feed-pump with their appendages. In this figure are also introduced external views of the air-pump rod and cross-head, and of the plunger-rod of the feed-pump.

Figs. 1462 and 1463 show the air-pump link.

Figs. 1464 and 1465 the connecting-rod.

Figs. 1466 and 1467 the long parallel-motion beams which work the air-pump.

Fig. 1468 the radius-rod for the parallel motion.

Literal references.—A, the sole-plate, of cast-iron, 2 inches thick, laid on a solid bed of African oak 16 inches thick, and cast so as to form the bottom of the cylinder. It is made of larger dimensions than are absolutely required for the attachment of the fixed parts of the engines, being extended to some distance on each side, in order to cover a larger space and to increase the strength of the keelsons and lower timbers of the ship. The sole-plate does not, however, on that account, occupy additional room, being so constructed as to form the flooring on every side, and at the same time to distribute the weight and action of the engines over a more extended surface of the flooring.

E, the steam-cylinder, $1\frac{3}{4}$ inch thick, cast open at each end, the sole-plate forming the cylinder bottom. Its internal diameter is 88 inches, and the stroke 5 feet 9 inches. Besides being strengthened by the flanges at the top and bottom, it is encircled by three belts, each 3 inches deep, in order to give rigidity to the cylinder when laid horizontal during the process of boring. It is now usual to bore cylinders of large diameter in a vertical position, to avoid all chance of ellipticity arising from this cause. The cylinder is fitted with escape-valves for priming or condensed water both above and below the piston, the valve being loaded to somewhat above the highest tension of the steam in the cylinder.

d d, the steam-ports, 3 feet 8 inches long, by $7\frac{5}{8}$ inches wide.

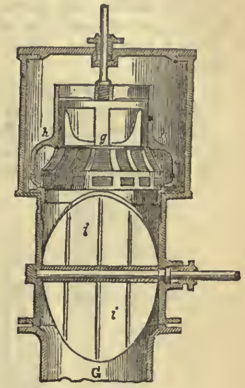
e, a separate casting for the cylinder face, planed and scraped to a true surface.

i, the throttle-valve, of gun-metal, worked by one of the three handles at *v'* through a series of rods and levers.

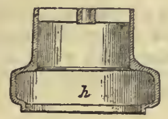
H, the steam-piston, $8\frac{3}{8}$ inches deep at the circumference, and $11\frac{3}{4}$ inches at the centre formed of cast-iron $1\frac{1}{2}$ inch thick, stiffened by radiating feathers.

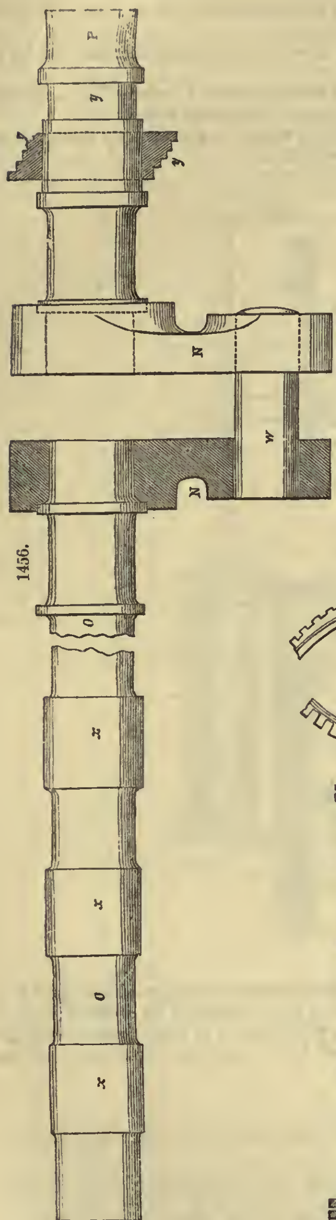
j, the external packing-rings, of cast-iron, 2½ inches deep, on Goodfellow's patent construction. These rings are turned concentric, and each, being cut across diagonally, to prevent grooving the cylinder, is free to accommodate itself to the interior of the cylinder as it wears by the friction of the piston, but possesses no elasticity in itself.

1459.



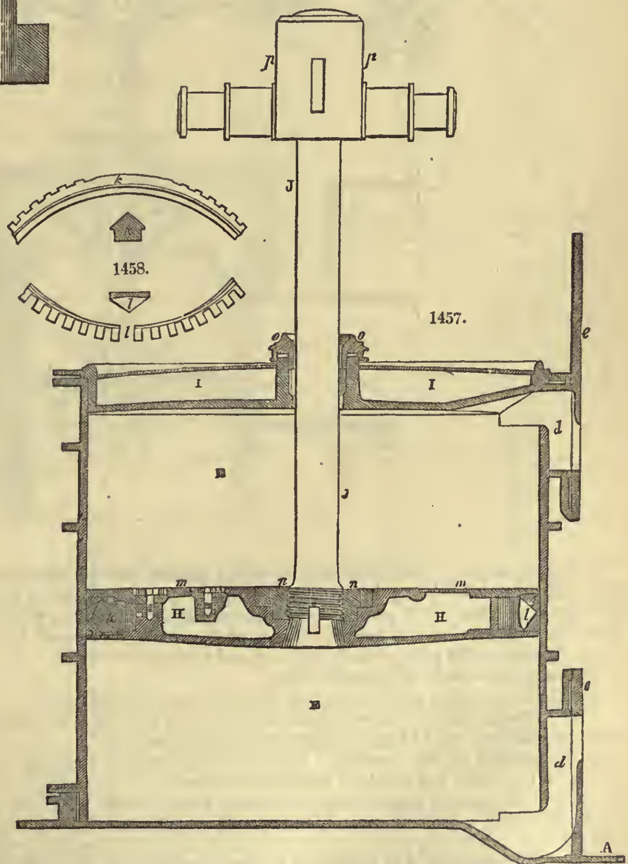
1460.





1456.

1458.



1457.

k and *l* represent the thick and thin ends of the inner eccentric V-shaped ring, of cast-iron, which, by its elasticity, presses the two external rings against the cylinder, thus forming a steam-tight joint. The requisite elasticity is given to this ring by forming in it a series of cuts or grooves increasing regularly in depth from *k*, where the ring is entire, to *l*, where the grooves are deepest; and also by causing the projections at the back of the rings shown at *k* to vanish at *l*. The ring is 4¾ inches deep, its thickness

being $5\frac{5}{8}$ inches at the thickest part, and $\frac{5}{8}$ inch at the thinnest. The grooves (86 in number) are, at the point *l*, $2\frac{3}{8}$ inches deep, and 7-16 inches wide, and they are pitched at $2\frac{1}{2}$ inches centre to centre.

m, the junk-ring, of cast-iron, $1\frac{1}{2}$ inch thick.

n, a brass nut for fixing the piston-rod.

I, the steam-cylinder cover, cast hollow, with radiating feathers, and with a thin polished plate of cast-iron for the upper part.

o, the stuffing-box gland, made so as to allow the strap of the connecting-rod to clear it on each side. It is formed of cast-iron, with a brass lining, and packed with hemp.

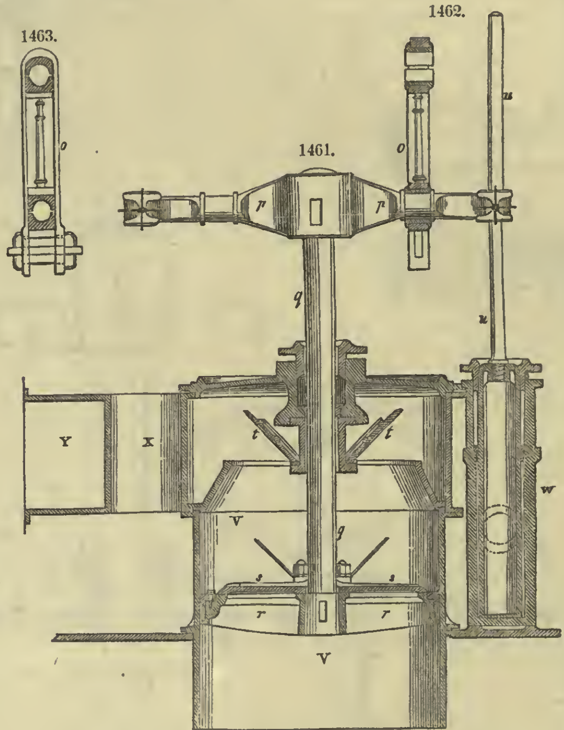
J, the piston-rod. It is fastened into the piston by a cone and screw *n*, and further secured by a cotter.

p, the piston cross-head, of forged iron, secured to the rod by a long cone and cotter. The bearings for the connecting-rod and the first parallel-motion beams are forged in one piece with it.

M, the connecting-rod, formed with a fork at the lower extremity, which is attached by straps, gibs, and cotters to the great bearings on each side of the piston cross-head *p*.

N, the crank, of wrought-iron.

1463. 1461. 1462.



w, the crank-pin. That portion of it which passes through the crank on the intermediate shaft P is firmly fixed to it by being driven into a slightly tapered eye, and is further secured by a cotter; but at the opposite extremity it passes loosely through the crank on the paddle-shaft, to allow for the deviation from the true vertical and horizontal lines of the shafts, occasioned by the unavoidable tendency of the outer bearing of the paddle-shaft to droop and to wear forwards.

O, the paddle-shaft, of wrought-iron.

x x x, bosses on the paddle-shaft for fixing the paddle-centres.

P, the intermediate shaft, which connects the two engines. The diameter at the centre is $18\frac{1}{2}$ inches, and the bearings are 17 inches diameter, by 18 inches long.

y, the position of the eccentric. In this, as in most other marine engines, the eccentric is not fixed firmly to the shaft, but revolves between the bearings shown at *y*, to admit of its turning the valves so as to give the engine motion either backwards or forwards. By placing the eccentric loose upon the shaft, only with a projecting catch on one side which is carried round by a corresponding projection on the shaft, it is left free, except when this check comes into contact with the other, at either end of the stroke. To effect this it is necessary to open the valves by hand during at least one-half stroke. The eccentric, of cast-iron, revolves within a ring of gun-metal. The throw of the eccentric is 20 inches; the diameter of the bearing surface is 3 feet $5\frac{5}{8}$ inches; the thickness of the gun-metal ring is $1\frac{3}{4}$ inch, and the breadth 4 inches.

o, the air-pump links. Thickness of strap, $1\frac{3}{8}$ inch· the column $2\frac{3}{8}$ inches, tapered to $1\frac{5}{8}$ inch diameter.

p, the air-pump cross-head. The diameter over the boss is 11½ inches; diameter of hollow cone, 5 7-16 inches, tapered to 5½ inches; thickness of blade, 3 inches.

q, the air-pump rod, formed of wrought-iron, cased with gun-metal, ½ inch thick when finished, cast round the rod and the cone, to prevent galvanic action.

r, the air-pump bucket, of gun-metal, packed with hemp.

s s, the bucket-valves, of gun-metal, of the description commonly called *butterfly-valves.* They work on a curved hinge encircling the pump-rod.

t t, discharge valves, also of gun metal, and of the same construction as the bucket-valves.

U, the condenser, of cast-iron, 1¼ inch thick. It is cast in one piece for both engines, with a partition through the middle to keep the condenser of each distinct from the other. There is a passage-way through the lower part of the condenser to the valve-jackets, in order to gain access to the valve-ports for packing them.

V, the air-pump, of solid gun-metal, ¾ inch thick when finished, 48 inches diameter, and 34½ inches stroke.

W, the feed-pump, with brass plunger, 9½ inches external diameter, and 34½ inches stroke.

Y, the discharge-pipe, of cast-iron, forming the top of the air-pump. From the air-pump to the sluice-valve through the ship's side, it becomes a circular copper pipe, 21½ inches bore.

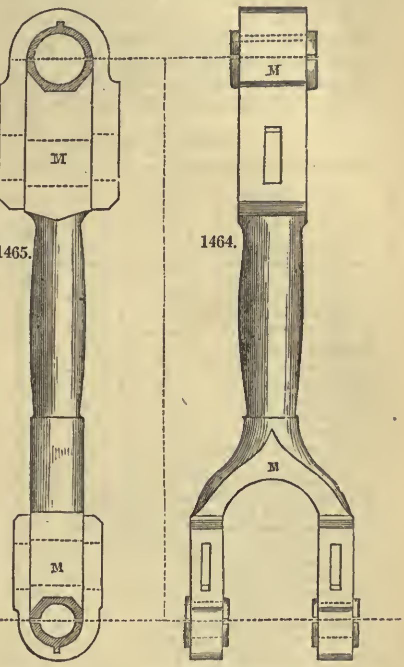
Z, the supplementary engine for feeding the boilers previous to starting the large engines.

v v v, a combination of levers and rods for working.

w, the injection-valve.

x, the blow-through or snifting-valve, and *i*, the throttle-valve. The connections for each valve are distinctly shown in the elevation.

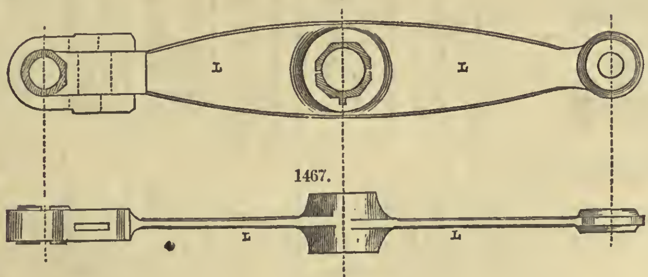
y, a graduated cam on the intermediate shaft for working the expansion geer.



1465. 1464.

z z z, a brass roller, levers, and rods for conveying the motion from the cam to the expansion-valve. The roller is adjusted to each cam by a screw, according to the amount of expansion required.

1466.



1467.

1468.

ENGINES, *for further details of,* See MARINE, LOCOMOTIVE, STATIONARY, PUMPING, HIGH-PRESSURE. NON-CONDENSING, &c., &c.

ENGINES, *rules for calculating the parts of.* Rules and tables for facilitating the construction of boilers, &c., by determining the lengths of plate or angle-iron requisite for the formation of hoops of different diameters. For plate or flat bar:—

Rule.—Add the thickness of the bar to the required diameter, and the corresponding circumference in the table of circumferences of circles is the length of the bar.

If the iron be bent edgewise the breadth of the bar must be added to the diameter; for it is the thickness of the bar measured radially that is to be taken into consideration.

In such pieces of work as the tires of railway wheels, which have a flange on one edge, it is necessary to add, not only the thickness of the tire, but also two-thirds of the thickness of the flange. Generally, however, the tire bars are sent from the iron works so curved that the plain edge of the tire is concave and the flange edge convex; while the side which is afterwards to be bent into contact with the cylin

drical surface of the wheel is a plane. By this means the addition to the diameter of two-thirds the thickness of the flange is unnecessary; for the curving of the flange edge has the effect of increasing the real length when only the chord of the arc is measured for the circumference. The radius of the curve in which the tires are first bent may be safely taken as four times the circumference of the hoop or wheel. In the form of rules, these results will be, first: when the tire is straight—

Rule.—Add the thickness of the hoop, and two-thirds the thickness of the flange to the diameter, and find the corresponding circumference.

And when the tire is curved it will be:—

Add the thickness of the hoop to the diameter, and find the circumference.

TABLE OF DIMENSIONS OF THE PARTS OF LOCOMOTIVE ENGINES.

	Railways.					
	Belgium.	Bordeaux and La Teste.	North Midland Cos.	Northern and Eastern Cos.	Great Western.	Hartlepool.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Width of railwsy hetween rails	4 8½	4 8½	4 8½	5 0	7 0	4 8½
Diameter of boiler (inside)	3 4¾	3 1⅜	3 7¼	3 7¼	3 11¼	3 5¼
Length of ditto	8 2	8 9	8 6	8 0	8 6	8 6
Thickness of plates	0 0⅜	0 $0\frac{5}{16}$	0 0⅜	0 0⅜	0 0⅜	0 0⅜
Length of outside fire-box	3 8¾	3 4½	4 0	4 0¼	4 6	3 7
Breadth of ditto	4 0	3 9½	4 0	4 0¼	4 8	4 1
Depth below boiler	2 0	1 8	2 2	2 2	2 3	2 0½
Height above ditto	0 4¼	not ascertained	2 7	2 7	2 1	0 4¼
Thickness of plates	0 0⅜	0 0⅜	0 0⅜	0 0⅜	0 0⅜	0 0⅜
Length of *inside* fire-box	3 0¼	2 8	3 3⅝	3 3¾	3 8⅛	2 10½
Breadth of ditto	3 4½	3 2	3 4⅝	3 4¾	3 10⅞	3 5¼
Thickness of copper plates	0 0⅝	0 0⅝	0 0⅜	0 0⅝	0 0½	0 0½
Extra thickness of ditto for insertion of tubes	0 0⅜	0 0⅜	0 0⅜	0 0⅜	0 0⅜	0 0¼
From bottom of fire-box to top of fire-bars	0 8	....	0 9	....	0 9	0 8
From top of fire-bars to crown of fire-box	3 4½	....	3 7½	....	....	3 5
Area of fire-grate in superficial feet	10 2½	....	11 2	11 3	12 10	9 10½
Length of smoke-box (inside)	1 11¾	1 11⅞	2 1	2 1	2 2½	2 1
Breadth of ditto (outside)	3 11½	4 1	4 2	4 2¾	5 2⅛	4 2
Thickness of tube-plate	0 0½	0 0½	0 0½	0 0½	0 0⅝	0 0½
Thickness of side-plates	0 0¼	0 0¼	0 0¼	0 0¼	0 0¼	0 0¼
Diameter of chimney (inside)	1 0¾	1 0	1 2	1 2	1 4	1 2
Height of top of ditto from rails	....	13 0	14 0	13 6	14 10	13 6
Number of brass tubes	86	94	123	121	131	105
Exterior of diameter of ditto	0 2¼	0 2	115 at 2, 8 at 1⅝	0 2	127 at 2 & 4 at 1⅝	0 2
Thickness of tubes.—Wire gage	No. 14	No. 14	No. 14	No. 14	No. 12	No. 14
Distance from centre to centre of tubes	0 3	0 2¾	0 2¾	0 2¾	0 2⅞	0 2¾
Diameter of steam-dome (inside)	1 5	....	....	....	....	1 7
Height of ditto	2 7⅝	....	....	....	....	2 7⅜
Diameter of safety-valves	2½ & 3	3¼ & 3¼	4 & 4	4 & 4	3¼ & 3¼	2½ & 3
Diameter of inside copper steam-pipe	0 5	0 5	0 6¼	0 6¼	0 6¼	0 6¼
Thickness of ditto.—Wire gage	No. 10	No. 10	....	....	No. 10	No. 10
Diameter of branch steam-pipe (inside)	0 3½	0 3½	0 4½	0 4½	0 4½	0 4½
Diameter of top of blast-pipe (inside)	0 2½	0 2½	0 3	0 3	0 3⅝	0 3
Diameter of cylinders	1 0½	1 0	1 2	1 2	1 3	1 2
Length of stroke	1 6	1 6	1 6	1 6	1 6	1 6
Distance of centres of cylinders	2 5	2 5	2 5	2 5	3 0	2 5
Size of steam-ports	11 × 1	9½ × 1	11 × 1¼	11 × 1¼	11 × 1¼	11 × 1¼
Size of eduction-ports	11 × 2	9½ × 2	11 × 2½	11 × 2½	11 × 2⅝	11 × 2½
Breadth of bridge between ports	0 0¾	0 0¾	0 0⅝	0 0⅝	0 0⅝	0 0⅝
Lead of slide-valves	0 $0\frac{3}{16}$	0 0¼	0 $0\frac{3}{16}$	0 $0\frac{3}{16}$	....	0 $0\frac{3}{16}$
Cover of ditto	0 $0\frac{5}{16}$	0 0⅝	0 0½	0 0⅛	0 0¾	0 $0\frac{5}{16}$
Distance from centre of cylinder to centre of steam-chest	0 11	....	1 0⅛	1 0⅛	1 2	1 0⅛
Thickness of piston	3⅜	3⅜	4¼	4¼	4	4¼
Diameter of piston-rod	2	2	2	2	2¼	2
Diameter of valve-spindle	0⅞	1	1	1	1⅛	1
Diameter of pump-ram	1⅞	2	2	2	2¼	2
Length of pump-lever	6¾	None	6¾	6¾	None	$6\frac{5}{16}$
Diameter of ball-valves	2	$2\frac{7}{16}$	$2\frac{7}{16}$	$2\frac{7}{16}$	2½	$2\frac{7}{16}$
Diameter of union and section pipes (inside)	1¾	1¾	1¾	1¾	2¼	1¾
Diameter of driving-wheels	5 6	6 0	5 0	6 0	7 0	4 6
Tyres of ditto in centre of tread	....	6 × 1¾	7 × 1¾	7 × 1¾	5½ × 2	5½ × 1⅜
Diameter of leading-wheels	3 9	4 0	5 0	4 0⅜	4 0	4 6
Tires of ditto	....	5½ × 1⅝	6 × 1¾	6 × 0	5½ × 2	5½ × 1⅜
Diameter of trailing-wheels	3 9	4 0	3 6	4 0	4 0	None
Tires of ditto	....	5½ × 1⅜	6 × 1⅝	6 × 1⅜	5½ × 2	
Diameter of plain part of cranked axle	4¾	5	5⅛	5⅛	6½	5⅞
Diameter of inside bearings	5	5	5¾	5¾	6⅛	5⅜
Length of ditto	3¼ & 3	3	3¼ & 3	3⅜ & 3	4	3
Radius of ditto	3 & 2⅜	2⅜	$2\frac{15}{16} \times 2\frac{9}{16}$	$2\frac{9}{16}$ & $2\frac{15}{16}$	5½	$2\frac{9}{16}$
Diameter of crank-pins	5	5	5¾	5¾	6⅛	5⅜
Length of ditto	3	3	3	3	4	3
Radius of ditto	2⅜	2⅜	$2\frac{9}{16}$	$2\frac{9}{16}$	5⅛	$2\frac{9}{16}$
Diameter of outside bearings	3¼	3¼	3¾	3¾	4	3½
Length of ditto	5½	5⅛	5⅛	5⅛	6¾	5⅜
Diameter of bosses on axles for eccentrics	6⅜ & 4¾	5 & 5	7 & 5⅛	7 × 5⅛	7¼ & 6⅛	7 × 5⅞
Diameter of bosses for driving-wheels	6¼	6⅛	6½	6⅛	7¼	6⅜
Length of bosses for ditto	7½	7⅝	8⅛	7⅞	....	7¼
Diameter of axle for leading-wheels	3¾	4	5	4⅛	6¼ & 4¾	4¾

TABLE OF DIMENSIONS OF THE PARTS OF LOCOMOTIVE ENGINES.—(Continued.)

	RAILWAYS.											
	Belgium.		Bordeaux and La Teste.		North Midland Cos.		Northern and Eastern Cos.		Great Western.		Hartlepool.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
Diameter of bearings for leading-wheels . .		3½		3⅛		3¾		3¾		3½		3½
Length of bearings for ditto		5½		5½		5½		5½		6¼		5½
Diameter of boss for wheels		4½		5		6½		5½		5¾		5½
Length of boss for ditto.		6¾		7		8⅛		7⅝		8		
Diameter of axle for trailing-wheels		3¾		4		4½		4½	6¼×4½			
Diameter of bearings.		3⅛		3⅛		3¾		3¾		3⅛		
Length of bearings		5½		5½		5½		5½		6¼		
Diameter of boss for wheels		4½		5		5		5½		5¾		
Length of boss		6¾		7		8		7⅜		8		
Diameter of boss on axle for outside cranks	None		None			4¾	....		None			4¼
Length of ditto.	....		....			3⅜	....		....			3⅛
Length of outside cranks from centre to centre	None		None		1	1½	....		None		1	1½
Diameter of plain pin on ditto	....		....			1¾	....		....			1¾
Length of plain pin	....		....			2	....		None			2
Diameter of ball pin	....		....			$2\frac{11}{16}$	....		....			2⅝
Outside frame (extreme breadth)	6	4	6	4	6	5	6	8¼	8	9¼	6	3¾
Length of ditto	18	3	18	2½	18	3	18	2¼	20	4	18	3
Depth of frame sides.		7		7		7¼		7¼		8		7¼
Thickness of ditto		4		4		4		4		4¼		4
Thickness of side-plates		0⅜		0⅜		0⅜		0⅜		0⅜		0⅜
Thickness of horn-plates		0⅝		0⅜		0⅜		0⅜		0½		0⅛
Length of driving-wheel springs	2	8	....		2	9	2	9	2	6		
Breadth of ditto		3⅞	....			3⅞		3⅝		3¼		
Number of plates	2 at 0⅜ 12 at 0¼		....		1 at 0⅜ 12 at $0\frac{5}{16}$		1 at 0⅜ 14 at $0\frac{15}{16}$		2 at 0⅜ 10 at $0\frac{5}{16}$			
Length of leading-wheel springs	Ellip. 2	2	....		2	9	Ellip 2	0	2	3		
Breadth of ditto		3	....			4		3		3¼		
Number of plates	2 at $0\frac{5}{16}$ 11 at 0¼		....		1 at 0⅜ 14 at $0\frac{5}{16}$		1 at 0⅜ 11 at $0\frac{5}{16}$		2 at 0⅜ 10 at $0\frac{5}{16}$			
Length of trailing-wheel springs	Ellip. 2	2	....		Ellip 2	0	Ellip 2	0	2	3		
Breadth of ditto		3	....			3		3		3¼		
Number of plates	2 at $0\frac{5}{16}$ 8 at 0¼		....		1 at 0⅜ 6 at $0\frac{5}{16}$		1 at 0⅜ 6 at $5\frac{5}{16}$		2 at 0⅜ 8 at $0\frac{5}{16}$			
Diameter of eccentrics	10⅝ & 12½			10⅞	1	1	1	1	1	1¾	12½×11⅞	
Throw of ditto		1¾		1⅛		$1\frac{13}{16}$		$1\frac{13}{16}$		1¾		$1\frac{9}{16}$
Breadth of ditto (brass hoops)		1¾		1¾		2¼		2¼	Iron	1¾		1¾
Diameter of valve-geer shafts		2⅛		2⅛		2⅛		2⅛		2¼		2⅛
Diameter of journals to ditto		1¾		1¾		1¾		1¾		2		1⅞
Length of journal		2½		2½		2½		2½		2¾		2¾
Length of side-levers		5		5		6		6		6⅛		6
Length of fork-end levers		6½	5 &	$4\frac{1}{16}$		6		6		5¾		6
Diameter of ferules		1⅝		1⅞		1⅞		1⅞		1⅞		2
Length of lifting levers		10	1	0	1	0	1	0	1	3	1	0
Length of reversing levers	12 & 10		1	0	12 & 10		12 & 10		1	3	1	0
Distance between motion bars		8½		7⅞		7		7¾	1	0¾		
Diameter of ball on cross-head spindle . . .		3		3		3⅛		3⅛		3⅜		3⅛
Diameter of connecting-rods in middle . .	....			2½		2⅝		2⅝		2¾		2⅝
Inside horn-bars	4 × 1		3¾ ×	1⅛	3½×1¾		3¼×1¾		4½×1½		3¼×1½	
Distance from centre of crank-axle to fire-box	1	6	1	6	1	6	1	6	1	5⅝	1	3
Distance from centre of crank-axle to centre of leading-axle	5	6	6	2	5	6	5	7	6	7	5	10½
Distance from centre of crank-axle to centre of trailing-axle	5	6	5	3½	5	9	5	9½	6	7	None	

In the construction of the boilers for these engines, the cylindrical parts of each are fixed to the smoke and fire-boxes, by 2½ inch angle-irons round the upper, and 3 inch angle-irons round the lower half of the boiler, firmly riveted with ¾ of an inch rivets. The tops of the outside fire-boxes of the engines for the North Midland, Northern and Eastern Counties, and the Great Western Railways, are worked into a dome-shaped figure, by which means the advantage is obtained of placing the regulator, with its appendages, immediately over the inside fire-box. The man-hole, being also placed in this dome, admits of a free access to the interior of the boiler.

The outside fire-boxes for the engines of the Belgium railways, having low semicircular tops, the steam domes are fixed on the cylindrical part of the boiler, and the regulators fixed to the tube-plate of the smoke-box. The inside fire-boxes are formed of copper plates of the dimension shown; that portion of the tube-plate, necessary for the insertion of the tubes, being increased in thickness in order tc increase its stability, as well as to assist in the more perfect securing of the tubes. The opening, in the frcnt plate for the smoke-box doors, is, in all respects, sufficiently large to admit of free working-room, for the removal and reinstatement of the copper tubes of the boiler, as occasion may require.

In the inside fire-boxes of the engines for the Great Western Railway, there are low hollow partitions, forming a clear water-space of four inches across the box; in the sides of this box, to which the partition is riveted, apertures, eight by four inches, are cut so as to allow of the free escape of steam from this division. The cylinders in the whole of the engines here enumerated are fixed in the lower part of the cavity of the smoke-box, and firmly bolted to the front and back plates, these plates being cut to receive the same. The pipes from the eduction ports (excepting in the engines for the Great

Western Railway) are cast on the body of the cylinders, and extending across towards the middle, and uniting with its corresponding pipe, is strongly bolted thereto; on the upper surfaces of these pipes, flanches are cast with a horizontal plane, upon which the blast-pipes are fixed. The blast-pipe of copper, of a conical or pyramidal shape, formed with flanches at the bottom, is placed immediately over the junction of the pipes from the eduction ports, and firmly bolted thereto.

The pumps are fixed either directly or indirectly to the outer bars of the inside framework, as the shape and position of the parts may require; the rams of the engines for the Great Western Railway are worked immediately from the spindle of the cross-head; those of the North Midland and the Belgium engines, by an arm or lever attached to the piston-rod. The whole of the valve-geer, as well as the carriages for the cross-head guide-bars are supported in their position by strong iron framework, technically called horn-bars. These bars extend from the back plate of the smoke-box to the front plate of the outside fire-box, and are bolted to lugs fixed thereon to receive the ends of the bars. These bars also serve the purpose of staying the crank axle by means of horns, which are worked on the bars, and in which the bearings are fixed. The inner horn-bars of the engines for the North Midland, the Belgium, and the North Eastern Railways, extend in a parallel direction, from the smoke-box to the extreme length of the guide-bars; and from thence obliquely in a Y-shaped form, uniting with each other, and forming, with the two outside horn-bars, a third stay to the crank axle.

The construction of the valve-geer of the engine for the Bordeaux and La Teste Railway, differs widely in its details from the rest of the engines here noted. The eccentric bosses are placed close to each other, in the middle of the driving-wheel axle, the end of each eccentric-rod being furnished with a pin on which the ferules are placed, instead of forked ends, as have been hitherto generally adopted. On the shaft which gives motion to the valve lever is fixed a double lever, with forked ends; in the hollow of each fork a socket is formed for the reception of the pin and ferule on the end of the eccentric-rod; and of such depth as to allow the lever to have a throw, variable from $4\frac{1}{16}$ to 5 inches. Each of these fork-ended levers are placed in a vertical position with each other, but acting in opposite directions upon the inner end of the valve-shaft. The eccentric-rod ends are connected with a lever on the reversing shaft, by lifting and lowering links, which not only admit of the eccentrics being thrown in or out of geer, but also allow of a greater or less degree of travel to the side valve, by increasing or diminishing the throw of the fork-ended lever. The peculiar advantage of the plan thus adopted is obvious from the economy in the saving of steam, the travel of the slide being regulated so as to admit of no more steam into the cylinder than what is necessary to propel the engine at the velocity required. The link motion has, to a great extent, superseded the fork-ended levers, and it is a greatly preferable arrangement.

RULES FOR THE CALCULATION OF THE PARTS OF MARINE ENGINES.

Rule 1.—*To find the breadth of crank at paddle centre.*—Multiply the square of the length of the crank in inches by 1·561, and then multiply the square of the diameter of cylinder in inches by ·1235; multiply the square root of the sum of these products by the square of the diameter of the cylinder in inches; divide the product by 45; finally, extract the cube root of the quotient. The result is the breadth of the web of crank at paddle centre.

EXAMPLE.

$$\begin{array}{rl}
48 & = \text{length of crank in inches.} \\
48 & \\
\hline
2304 & \\
1·561 & = \text{constant multiplier.} \\
\hline
3596.5 & \\
505·8 & \\
\hline
4102·3 &
\end{array}$$

$$\begin{array}{rl}
64 & = \text{diameter of cylinder.} \\
64 & \\
\hline
4096 & \\
·1235 & = \text{constant multiplier.} \\
\hline
505·8 &
\end{array}$$

$$\text{and } \sqrt{4102·3} = 64·05 \text{ nearly.}$$

$$\begin{array}{rl}
 & 4096 = \text{square of the diameter of the cylinder.} \\
45) & \overline{262348·5} \\
 & 5829·97
\end{array}$$

$$\text{and } \sqrt[3]{5829·97} = 18 \text{ nearly.}$$

Rule 2.—*To find the thickness of large eye of crank.*—Multiply the square of the length of the crank in inches by 1·561, and then multiply the square of the diameter of the cylinder in inches by ·1235; multiply the sum of these products by the square of the diameter of the cylinder in inches; afterwards, divide the product by 1828·28; divide this quotient by the length of the crank in inches; finally, extract the cube root of the quotient. The result is the proper thickness of the large eye of crank in inches.

EXAMPLE.

48 = length of crank in inches.
48
2304
1·561 = constant multiplier.
3596·5
505·8
4102·3

64 = diameter of cylinder in inches.
64
4096
·1235 = constant multiplier.
505·8

4102·3
4096 = square of diameter.
48) 16803020·8
1828·28) 350062·94
191·47

and $\sqrt[3]{191·47} = 5·77$ nearly.

Rule 3.—*To find the thickness of the web of crank at paddle-shaft centre.*—Multiply the square of the length of crank in inches by 1·561, and then multiply the square of the diameter in inches by ·1235, multiply the square root of the sum of these products by the square of the diameter of the cylinder in inches; divide this quotient by 360; finally, extract the cube root of the quotient. The result is the thickness of the web of crank at paddle-shaft centre in inches.

Thus to apply the rule to the particular example which we have selected, we have

48 = length of crank in inches.
48
2304
1·561 = constant multiplier.
3596·5
505·8
4102·3

64 = diameter of cylinder.
64
4096
·1235 = constant multiplier.
505·8

And $\sqrt{4102·3} = 64·05$ nearly
4096 = square of diameter.
360)262348·5
728·75

And $\sqrt[3]{728·75} = 9$ nearly.

Rule 4.—*To find the diameter of the paddle-shaft journal.*—Multiply the square of the diameter of cylinder in inches by the length of the crank in inches; extract the cube root of the product; finally multiply the result by ·242. The final product is the diameter of the paddle-shaft journal in inches.

Rule 5.—*To find the length of the paddle-shaft journal.*—Multiply the square of the diameter of the cylinder in inches by the length of the crank in inches; extract the cube root of the quotient; multiply the result by ·303. The product is the length of the paddle-shaft journal in inches. (The length of the paddle-shaft journal is 1¼ times the diameter.)

Rule 6.—*To find the diameter of crank-pin journal.*—Multiply the diameter of the cylinder in inches by ·142. The result is the diameter of crank-pin journal in inches.

Rule 7.—*To find the length of crank-pin journal.*—Multiply the diameter of the cylinder in inches by ·16. The product is the length of the crank-pin journal in inches.

Rule 8.—*To find the breadth of the eye of cross-head.*—Multiply the diameter of the cylinder in inches by ·041. The product is the breadth of the eye in inches.

Rule 9.—*To find the depth of the eye of cross-head.*—Multiply the diameter of the cylinder in inches by ·286. The product is the depth of the eye of cross-head in inches.

Rule 10.—*To find the diameter of the journal of cross-head.*—Multiply the diameter of the cylinder in inches by ·086. The product is the diameter of the journal in inches.

Rule 11.—*To find the length of the journal of cross-head.*—Multiply the diameter of the cylinder in inches by ·097. The product is the length of the journal in inches.

Rule 12.—*To find the thickness of the web of cross-head at middle.*—Multiply the diameter of the cylinder in inches by ·072. The product is the thickness of the web of cross-head at middle in inches.

Rule 13.—*To find the breadth of web of cross-head at middle.*—Multiply the diameter of the cylinder in inches by ·268. The product is the breadth of the web of cross-head at middle in inches.

Rule 14.—*To find the thickness of the web of cross-head at journal.*—Multiply the diameter of the cylinder in inches by ·061. The product is the thickness of the web of cross-head at journal in inches.

Rule 15.—*To find the breadth of web of cross-head at journal.*—Multiply the diameter of the cylinder in inches by ·101. The product is the breadth of the web of cross-head at journal in inches.

Rule 16.—*To find the diameter of the piston-rod.*—Divide the diameter of the cylinder in inches by 10. The quotient is the diameter of the piston-rod in inches.

Rule 17.—*To find the length of the part of the piston-rod in the piston.*—Divide the diameter of the cylinder in inches by 5. The quotient is the length of the part of the piston-rod in the piston in inches.

Rule 18.—*To find the major diameter of the part of piston-rod in cross-head.*—Multiply the diameter of the cylinder in inches by ·095. The product is the major diameter of the part of piston-rod in cross-head in inches.

Rule 19.—*To find the minor diameter of the part of piston-rod in cross-head.*—Multiply the diameter of the cylinder in inches by ·09. The product is the minor diameter of the part of piston-rod in cross-head in inches.

Rule 20.—*To find the major diameter of the part of piston-rod in piston.*—Multiply the diameter of the cylinder in inches by ·14. The product is the major diameter of the part of the piston-rod in piston in inches.

Rule 21.—*To find the minor diameter of the part of piston-rod in piston.*—Multiply the diameter of the cylinder in inches by ·115. The product is the minor diameter of the part of piston-rod in piston.

Rule 22.—*To find the depth of gibs and cutter through cross-head.*—Multiply the diameter of the cylinder in inches by ·105. The product is the depth of the gibs and cutter through cross-head.

Rule 23.—*To find the thickness of the gibs and cutter through cross-head.*—Multiply the diameter of the cylinder in inches by ·021. The product is the thickness of the gibs and cutter through cross-head.

Rule 24.—*To find the depth of cutter through piston.*—Multiply the diameter of the cylinder in inches by ·085. The product is the depth of the cutter through piston in inches.

Rule 25.—*To find the thickness of cutter through piston.*—Multiply the diameter of the cylinder in inches by ·035. The product is the thickness of cutter through piston in inches.

Rule 26.—*To find the diameter of connecting-rod at ends.*—Multiply the diameter of the cylinder in inches by ·095. The product is the diameter of the connecting-rod at ends in inches.

Rule 27.—*To find the major diameter of the part of connecting-rod in cross-tail.*—Multiply the diameter of the cylinder in inches by ·098. The product is the major diameter of the part of connecting-rod in cross-tail.

Rule 28.—*To find the minor diameter of the part of connecting-rod in cross-tail.*—Multiply the diameter of the cylinder in inches by ·09. The product is the minor diameter of the part of connecting-rod in cross-tail in inches.

Rule 29.—*To find the breadth of the butt.*—Multiply the diameter of the cylinder in inches by ·156 The product is the breadth of the butt in inches.

Rule 30.—*To find the thickness of the butt.*—Divide the diameter of the cylinder in inches by 8. The quotient is the thickness of the butt in inches.

Rule 31.—*To find the mean thickness of the strap at cutter.*—Multiply the diameter of the cylinder in inches by ·043. The product is the mean thickness of the strap at cutter.

Rule 32.—*To find the mean thickness of the strap above cutter.*—Multiply the diameter of the cylinder in inches by ·032. The product is the mean thickness of the strap above cutter.

Rule 33.—*To find the distance of cutter from end of strap.*—Multiply the diameter of the cylinder in inches by ·048. The product is the distance of cutter from end of strap in inches.

Rule 34.—*To find the breadth of the gibs and cutter through cross-tail.*—Multiply the diameter of the cylinder in inches by ·105. The product is the breadth of the gibs and cutter through cross-tail.

Rule 35.—*To find the breadth of the gibs and cutter through butt.*—Multiply the diameter of the cylinder in inches by ·11. The product is the breadth of the gibs and cutter through butt in inches.

Rule 36.—*To find the thickness of the gibs and cutter through butt.*—Multiply the diameter of the cylinder in inches by ·029. The product is the thickness of the gibs and cutter through butt in inches.

Rule 37.—*To find the breadth of the small eye of crank.*—Multiply the diameter of the cylinder in inches by ·063. The product is the proper breadth of the small eye of crank in inches.

Rule 38.—*To find the length of the small eye of crank.*—Multiply the diameter of the cylinder in inches by ·187. The product is the proper length of the small eye of crank in inches.

Rule 39.—*To find the thickness of the web of crank at pin centre.*—Multiply the diameter of the cylinder in inches by ·11. The product is the proper thickness of the web of crank at pin centre in inches.

Rule 40.—*To find the breadth of the web of crank at pin centre.*—Multiply the diameter of the cylinder in inches by ·16. The product is the proper breadth of crank at pin centre in inches.

Rule 41.—*To find the diameter of cylinder side-rods at ends.*—Multiply the diameter of the cylinder in inches by ·065. The product is the diameter of the cylinder side-rods at ends in inches.

Rule 42.—*To find the breadth of butt in inches.*—Multiply the diameter of the cylinder in inches by ·077. The product is the breadth of the butt in inches.

Rule 43.—*To find the thickness of the butt.*—Multiply the diameter of the cylinder in inches by .061. The product is the thickness of the butt in inches.

Rule 44.—*To find the mean thickness of strap at cutter.* Multiply the diameter of the cylinder in inches by ·032. The product is the mean thickness of the strap at cutter.

Rule 45.—*To find the mean thickness of strap below cutter.*—Multiply the diameter of the cylinder in inches by ·023. The product is the mean thickness of strap below cutter in inches.

Rule 46.—*To find the depth of gibs and cutter.*—Multiply the diameter of the cylinder in inches by ·08. The product is the depth of gibs and cutter in inches.

Rule 47.—*To find the thickness of gibs and cutter.* Multiply the diameter of the cylinder in inches by ·016. The product is the thickness of the gibs and cutter in inches.

Rule 48.—*To find the diameter of the main centre journal.*—Multiply the diameter of the cylinder in inches by ·183. The product is the diameter of the main centre journal in inches.

Rule 49.—*To find the length of the main centre journal.*—Multiply the diameter of the cylinder in inches by ·275. The product is the diameter of the cylinder in inches.

Rule 50.—*To find the depth of eye round end studs of lever.*—Multiply the diameter of the cylinder in inches by ·074. The product is the depth of the eye round end studs of lever in inches.

Rule 51.—*To find the thickness of eye round end studs of lever.*—Multiply the diameter of the cylinder in inches by ·052. The product is the thickness of eye round end studs of lever in inches.

Rule 52.—*To find the diameter of the end studs of lever.*—Multiply the diameter of the cylinder in inches by ·07. The product is the diameter of the end studs of lever in inches.

Rule 53.—*To find the length of the end studs of lever.*—Multiply the diameter of the cylinder in inches by ·076. The product is the length of the end studs of lever in inches.

Rule 54.—*To find the diameter of the air-pump studs.*—Multiply the diameter of the cylinder in inches by ·045. The product is the diameter of the air-pump studs in inches.

Rule 55.—*To find the length of the air-pump studs.*—Multiply the diameter of the cylinder in inches by ·049. The product is the length of the air-pump studs in inches.

Rule 56.—*To find the depth across the centre of the side lever.*—Multiply the length of the side lever in feet by ·7423; extract the cube root of the product, and reserve the result for a multiplier. Then square the diameter of the cylinder in inches; extract the cube root of the result. The product of the final result and the reserved multiplier is the depth of the side lever in inches across the centre.

Rule 57.—*To find the diameter of the air-pump.*—Multiply the diameter of the cylinder in inches by ·6. The product is the diameter of the air-pump in inches.

Rule 58.—*To find the thickness of the eye of air-pump cross-head.*—Multiply the diameter of the cylinder in inches by ·025. The product is the thickness of the eye of air-pump cross-head in inches.

Rule 59.—*To find the depth of eye of air-pump cross-head.*—Multiply the diameter of the cylinder in inches by ·171. The product is the depth of the eye of air-pump cross-head in inches.

Rule 60.—*To find the diameter of the journals of air-pump cross-head.*—Multiply the diameter of the cylinder in inches by ·051. The product is the diameter of the end journals.

Rule 61.—*To find the length of the end journals for air-pump cross-head.*—Multiply the diameter of the cylinder in inches by ·058. The product is the length of the air-pump cross-head journals in inches.

Rule 62.—*To find the thickness of the web of air-pump cross-head at middle.*—Multiply the diameter of the cylinder in inches by ·043. The product is the thickness at middle of the web of air-pump cross-head in inches.

Rule 63.—*To find the depth at middle of the web of air-pump cross-head.*—Multiply the diameter of the cylinder in inches by ·161. The product is the depth at middle of air-pump cross-head in inches.

Rule 64.—*To find the thickness of the web of air-pump cross-head at journals.*—Multiply the diameter of the cylinder in inches by ·037. The product is the thickness of the web of air-pump cross-head at journals in inches.

Rule 65.—*To find the depth of the air-pump cross-head web at journals.*—Multiply the diameter of the cylinder in inches by ·061. The product is the depth at journals of the web of air-pump cross-head.

Rule 66.—*To find the diameter of the air-pump piston-rod when of copper.*—Multiply the diameter of the cylinder in inches by ·067. The product is the diameter of the air-pump piston-rod, when of copper, in inches.

Rule 67.—*To find the depth of gibs and cutter through air-pump cross-head.*—Multiply the diameter of the cylinder in inches by ·063. The product is the depth of the gibs and cutter through air-pump cross-head in inches.

Rule 68.—*To find the thickness of the gibs and cutter through air-pump cross-head.*—Multiply the diameter of the cylinder in inches by ·013. The product is the thickness of the gibs and cutter in inches.

Rule 69.—*To find the depth of cutter through piston.*—Multiply the diameter of the cylinder in inches by ·051. The product is the depth of the cutter through piston in inches.

Rule 70.—*To find the thickness of cutter through air-pump piston.*—Multiply the diameter of the cylinder in inches by ·021. The product is the thickness of the cutter through air-pump piston.

Rule 71.—*To find the diameter of air-pump side-rod at ends.*—Multiply the diameter of the cylinder in inches by ·039. The product is the diameter of the air-pump side-rod at ends in inches.

Rule 72.—*To find the breadth of butt for air-pump.*—Multiply the diameter of the cylinder in inches by ·046. The product is the breadth of butt in inches.

Rule 73.—*To find the thickness of butt for air-pump.*—Multiply the diameter of the cylinder in inches by ·037. The product is the thickness of butt for air-pump in inches.

Rule 74.—*To find the mean thickness of strap at cutter.*—Multiply the diameter of the cylinder in inches by ·019. The product is the mean thickness of strap at cutter for air-pump in inches.

Rule 75.—*To find the mean thickness of strap below cutter.*—Multiply the diameter of the cylinder in inches by ·014. The product is the mean thickness of strap below cutter in inches.

Rule 76.—*To find the depth of gibs and cutter for air-pump.*—Multiply the diameter of the cylinder in inches by ·048. The product is the depth of gibs and cutter for air-pump in inches.

Rule 77.—*To find the thickness of gibs and cutter for air-pump.*—Divide the diameter of the cylinder in inches by 100. The quotient is the proper thickness of the gibs and cutter for air-pump in inches.

With regard to the following rule we may remark, that the area of the steam port ought to depend principally upon the cubical content of the cylinder, which again depends entirely upon the product of the square of the diameter of the cylinder and the length of the stroke of the engine. It is well known, however, that the quantity of steam admitted by a small hole does not bear so great a proportion to the quantity admitted by a larger one, as the area of the one does to the area of the other; and a certain allowance ought to be made for this. In the absence of correct theoretical information on this point, we have attempted to make a proper allowance by supplying a constant; but of course this plan ought only to be regarded as an approximation.

Rule 78.—*To find the area of each steam port.*—Multiply the square of the diameter of the cylinder in inches by the length of the stroke in feet; multiply this product by 11; divide the last product by 1800; and, finally, to the quotient add 8. The result is the area of each steam port in square inches.

To show the use of this rule, we shall apply it to a particular example. We shall apply it to an engine whose stroke is 6 feet, and diameter of cylinder 30 inches. Then, according to the rule, we have

$$\begin{array}{rl}
30 & = \text{diameter of the cylinder in inches.} \\
30 & \\ \hline
900 & = \text{square of diameter} \\
6 & = \text{length of stroke in feet.} \\ \hline
5400 & \\
11 & \\ \hline
59400 \div 1800 = 33 & \\
8 & = \text{constant to be added.} \\ \hline
41 & = \text{area of steam port in square inches.}
\end{array}$$

Rule 79.—*To find the diameter of branch steam-pipe.*—Multiply together the square of the diameter of the cylinder in inches, the length of the stroke in feet, and ·00498; to the product add 10·2, and extract the square root of the sum. The result is the diameter of the steam-pipe in inches.

Rule 80.—*To find the diameter of waste-water pipe.*—Multiply the square root of the nominal horse power of the engine by 1·2. The product is the diameter of the waste-water pipe in inches.

Rule 81.—*To find the area of foot-valve passage.*—Multiply the nominal horse power of the engine by 9; divide the product by 5; add 8 to the quotient. The sum is the area of foot-valve passage in square inches.

Rule 82.—*To find the area of injection-pipe.*—Multiply the nominal horse power of the engine by ·069; to the product add 2·81. The sum is the area of the injection-pipe in square inches.

Rule 83.—*To find the diameter of feed-pipe.*—Multiply the nominal horse power of the engine by ·04; to the product add 3; extract the square root of the sum. The result is the diameter of the feed-pipe in inches.

Rule 84.—*To find the diameter of waste-steam pipe.*—Multiply the collective nominal horse power of the engines by ·375; to the product add 16·875; extract the square root of the sum. The final result is the diameter of the waste-steam pipe in inches.

Rule 85.—*To find the diameter of the safety-valve when only one is used.*—To one-half the collective nominal horse power of the engines add 22·5; extract the square root of the sum. The result is the diameter of the safety-valve when only one is used.

Rule 86.—*To find the diameter of the safety-valve when two are used.*—Multiply the collective nominal horse power of the engines by ·25; to the product add 11·25; extract the square root of the sum. The result is the diameter of the safety-valve when two are used.

Rule 87.—*To find the diameter of the safety-valve when three are used.*—To one-sixth of the collective nominal horse power of the engines add 7·5; extract the square root of the sum. The result is the diameter of the safety-valve where three are used.

Rule 88.—*To find the diameter of the safety-valve when four are used.*—Multiply the collective nominal horse power of the engines by ·125; to the product add 5·625; extract the square root of the sum. The result is the diameter of the safety-valve when four are used.

Another rule for safety-valves, and a preferable one for low pressures, is to allow ·8 of a circular inch of area per nominal horse power.

Rule 89.—*To find the depth of the web at the centre of the main beam of a land engine.*—Multiply together the square of the diameter of the cylinder in inches, half the length of the main beam in feet,

and the number 3; extract the cube root of the product. The result is the proper depth of the web of the main beam across the centre in inches, when the main beam is constructed of cast-iron.

Rule 90.—*To find the depth of main beam at ends.*—Multiply together the square of the diameter of the cylinder in inches, half the length of the main beam in feet, and the number ·192; extract the cube root of the product. The result is the depth in inches of the main beam at ends, when of cast-iron.

Rule 91.—*To find the content of the feed-pump.*—Multiply the square of the diameter of the cylinder in inches by the length of the stroke in feet; divide the product by 30. The quotient is the content of the feed-pump in cubic inches.

Rule 92.—*To find the content of the cold-water pump.*—Multiply the square of the diameter of the cylinder in inches by the length of the stroke in feet; divide the product by 4400. The quotient is the content of the cold-water pump in cubic feet.

Rule 93.—*To find the thickness of the large eye of crank for fly-wheel shaft when of cast-iron.*—Multiply the square of the length of the crank in inches by 1·561, and then multiply the square of the diameter of the cylinder in inches by ·1235; multiply the sum of these products by the square of the diameter of cylinder in inches; divide this product by 666·283; divide this quotient by the length of the crank in inches; finally, extract the cube root of the quotient. The result is the proper thickness of the large eye of crank for fly-wheel shaft in inches, when of cast-iron.

Rule 94.—*To find the breadth of the web of crank at fly-wheel shaft, when of cast-iron.*—Multiply the square of the length of the crank in inches by 1·561, and then multiply the square of the diameter of the cylinder in inches by ·1235; multiply the square root of the sum of these products by the square of the diameter of the cylinder in inches; divide the product by 23·04, and finally extract the cube root of the quotient. The final result is the breadth of the crank at the centre of the fly-wheel shaft, when the crank is of cast-iron.

As this rule is rather complicated, we shall illustrate it by showing its application to the particular example of an engine whose stroke is 8 feet, and diameter of cylinder 64 inches. For this engine, following the directions of the rule, we have in succession,

$$\begin{array}{rl}
64 & = \text{diameter of cylinder in inches.} \\
64 & \\ \hline
4096 & = \text{square of the diameter of cylinder.} \\
\cdot1235 & = \text{constant multiplier.} \\ \hline
505\cdot8 &
\end{array}$$

$$\begin{array}{rl}
48 & = \text{length of crank in inches} \\
48 & \\ \hline
2304 & = \text{square of the length of crank.} \\
1\cdot561 & = \text{constant multiplier.} \\ \hline
3596\cdot5 & \\
505\cdot8 & \\ \hline
4102\cdot3 & = \text{sum of products.}
\end{array}$$

$$\sqrt{4102\cdot3} = 64\cdot05 \text{ nearly.}$$

$$\begin{array}{rl}
 & 4096 = \text{square of the diameter of cylinder.} \\
\text{constant divisor} = 23\cdot04) & \underline{262348\cdot5} \\
 & 11386\cdot66 \text{ nearly.}
\end{array}$$

$$\text{and } \sqrt[3]{11386\cdot66} = 22\cdot49.$$

Rule 95.—*To find the thickness of the web of crank at centre of fly-wheel shaft, when of cast-iron.*—Multiply the square of the length of the crank in inches by 1·561, and then multiply the square of the diameter of the cylinder in inches by ·1235; multiply the square root of the sum of these products by the square of the diameter of the cylinder in inches; divide this product by 184·32; finally, extract the cube root of the quotient. The result is the thickness of the web of crank at the centre of the fly-wheel shaft when of cast-iron, in inches.

As this rule is rather complicated, we shall illustrate it by applying it to the particular engine which we have already selected. For this engine we have in succession,

$$\begin{array}{rl}
48 & = \text{length of crank in inches.} \\
48 & \\ \hline
2304 & = \text{square of the length of crank.} \\
1\cdot561 & = \text{constant multiplier.} \\ \hline
3596\cdot5 &
\end{array}$$

$$\begin{array}{rl}
64 & = \text{diameter of cylinder in inches.} \\
64 & \\ \hline
4096 & = \text{square of the diameter of cylinder.} \\
\cdot1235 & = \text{constant multiplier.} \\ \hline
505\cdot8 & \\
3596\cdot5 & \\ \hline
4102\cdot3 & = \text{sum of products.}
\end{array}$$

and $\sqrt{4102 \cdot 3} = 64 \cdot 05$ nearly
$4096 =$ square of diameter.
Constant divisor $= 184 \cdot 32) 262348 \cdot 5$
$1423 \cdot 33$

and $\sqrt[3]{1423 \cdot 33} = 11 \cdot 25$.

Rule 96.—*To find the diameter of the fly-wheel shaft at smallest part, when it is of cast-iron.*—Multiply the square of the diameter of the cylinder in inches by the length of the crank in inches; extract the cube root of the product; finally multiply the result by ·3025. The result is the diameter of the fly-wheel shaft at smallest part in inches.

Rule 97.—*To find the sectional area of the rim of the fly-wheel, when of cast-iron.*—Multiply together the square of the diameter of the cylinder in inches, the square of the length of the stroke in feet, the cube root of the length of the stroke in feet, and 6·125; divide the final product by the cube of the diameter of the fly-wheel in feet. The quotient is the sectional area of the rim of fly-wheel in square inches, provided it is of cast-iron.

As this rule is rather complicated, we shall endeavor to illustrate it by showing its application to a particular engine. We shall apply the rule to determine the sectional area of the rim of fly-wheel for an engine whose stroke is 8 feet, diameter of cylinder 50 inches; the diameter of the fly-wheel being 20 feet. For this engine we have as follows:

2500 = square of the diameter of cylinder.
64 = square of the length of stroke.
160000
2 = cube root of the length of stroke.
320000
6·125 = constant multiplier.
1960000

therefore sectional area in square inches $= 1960000 \div 20^3 = 1960000 \div 8000 = 1960 \div 8 = 245$.

In the following formulæ we denote the diameter of the cylinder in inches by D, the length of the crank in inches by R, the length of the stroke in feet, and the nominal horse power of the engine by H. P.

Marine engines.—Dimensions of several of the parts of the side-lever.

Depth of eye round end studs of lever $= \cdot 074 \times D$.
Thickness of eye round end studs of lever $= \cdot 052 \times D$.
Diameter of end studs, in inches $= \cdot 07 \times D$.
Length of end studs, in inches $= \cdot 076 \times D$.
Diameter of air-pump studs, in inches $= \cdot 045 \times D$.
Length of air-pump studs, in inches $= \cdot 049 \times D$.
Depth of cast-iron side-lever across centre, in inches $= D^{\frac{2}{3}} \times (\cdot 7423 \times \text{length of lever in feet})^{\frac{1}{3}}$.

Marine engine.—Dimensions of several parts of air-pump cross-head.

Diameter of air-pump, in inches $= \cdot 6 \times D$.
Thickness of eye for air-pump rod, in inches $= \cdot 025 \times D$.
Depth of eye for air-pump rod, in inches $= \cdot 171 \times D$.
Diameter of end journals, in inches $= \cdot 051 \times D$.
Length of end journals, in inches $= \cdot 058 \times D$.
Thickness of web at middle, in inches $= \cdot 043 \times D$
Depth of web at middle, in inches $= \cdot 161 \times D$.
Thickness of web at journal $= \cdot 037 \times D$.
Depth of web at journal $= \cdot 061 \times D$.

Marine engine.—Dimensions of the parts of air-pump piston-rod.

Diameter of air-pump piston-rod when of copper, in inches $= \cdot 067 \times D$.
Depth of gibs and cutter through cross-head, in inches $= \cdot 063 \times D$.
Thickness of gibs and cutter through cross-head, in inches $= \cdot 013 \times D$.
Depth of cutter through piston, in inches $= \cdot 051 \times D$.
Thickness of cutter through piston, in inches $= \cdot 021 \times D$.

Marine engine.—Dimensions of the remaining parts of the air-pump machinery.

Diameter of air-pump side-rods at ends, in inches $= \cdot 039 \times D$.
Breadth of butt, in inches $= \cdot 046 \times D$.
Thickness of butt, in inches $= \cdot 037 \times D$.
Mean thickness of strap at cutter, in inches $= \cdot 019 \times D$.
Mean thickness of strap below cutter, in inches $= \cdot 014 \times D$.
Depth of gibs and cutter, in inches $= \cdot 048 \times D$.
Thickness of gibs and cutter, in inches $= D \div 100$.

Marine and land engines.—Area of steam ports.

Area of each steam port, in square inches $= 11 \times l \times D^2 \div 1800 + 8$

Marine and land engines.—Dimensions of branch steam-pipes.

Diameter of each branch steam-pipe $= \sqrt{\cdot 00498 \times l \times D^2 + 10\cdot 2}$.

Marine engine.—Dimensions of several of the pipes connected with the engine.

Diameter of waste water-pipe, in inches $= 1\cdot 2 \times \sqrt{\text{H. P.}}$
Area of foot-valve passage, in square inches $= 1.8 \times \text{H. P.} + 8$.
Area of injection-pipe, in square inches $= \cdot 069 \times \text{H. P.} + 2\cdot 81$.
Diameter of feed-pipe, in inches $= \sqrt{\cdot 04 \times \text{H. P.} + 3}$.
Diameter of waste steam-pipe, in inches $= \sqrt{\cdot 375 \times \text{H. P.} + 16\cdot 875}$.

Marine and land engines.—Dimensions of safety-valves.

Diameter of safety-valve, when one only is used $= \sqrt{\cdot 5 \times \text{H. P.} + 22\cdot 5}$.
Diameter of safety-valve, when two are used $= \sqrt{\cdot 25 \times \text{H. P.} + 11\cdot 25}$.
Diameter of safety-valve, when three are used $= \sqrt{\cdot 167 \times \text{H. P.} + 7\cdot 5}$.
Diameter of safety-valve, when four are used $= \sqrt{\cdot 125 \times \text{H. P.} + 5\cdot 625}$.

Land engine.—Dimensions of main beam.

Depth of web of main beam across centre $= \sqrt[3]{3 \times D^2 \times \text{half length of main beam, in feet}}$.
Depth of main beam at ends $= \sqrt[3]{\cdot 192 \times D^2 \times \text{half length of main beam, in feet}}$.

Land and Marine-engines.—Content of feed-pump.

Content of feed-pump, in cubic inches $= D^2 \times l \div 30$.

Land engines.—Content of cold-water pump.

Content of cold-water pump, in cubic feet $= D^2 \times l \div 4400$.

Land engines.—Dimensions of crank.

Thickness of large eye of crank, in inches $= \sqrt[3]{D^2 \times (1\cdot 561 \times R^2 + \cdot 1235\, D^2) \div (R \times 666\cdot 283.)}$
Breadth of web of crank at fly-wheel shaft centre, in inches $=$

$$\sqrt[3]{D^2 \times \sqrt[2]{(1\cdot 561 \times R^2 + \cdot 1235 \times D^2)} \div 23\cdot 04}.$$

Thickness of web of crank at fly-wheel shaft centre, in inches $=$

$$\sqrt[3]{D^2 \times \sqrt[2]{(1\cdot 561 \times R^2 + \cdot 1235 \times D^2)} \div 184\cdot 32}.$$

Land engines.—Dimensions of fly-wheel shaft.

Diameter of fly-wheel shaft, when of cast-iron, $= 3025 \times \sqrt[3]{R \times D^2}$.

DIMENSIONS OF PARTS OF LOCOMOTIVES.

Diameter of cylinder.—In locomotive engines the diameter of the cylinder varies less than in either the land or the marine engine. In few of the locomotive engines at present in use is the diameter of the cylinder greater than 18 inches, or less than 12 inches. The length of the stroke of nearly all the locomotive engines at present in use is 18 inches, and there are always two cylinders, which are generally connected to cranks upon the axle, standing at right angles with one another. Outside cylinders, operating upon pins in the driving-wheels, have latterly been largely introduced.

Area of induction ports.

Rule.—To find the size of the steam ports for the locomotive engine.—Multiply the square of the diameter of the cylinder by ·068. The product is the proper size of the steam ports in square inches.

Example.—Required the proper size of the steam ports of a locomotive engine whose diameter is 15 inches. Here, according to the rule, size of steam ports $= \cdot 068 \times 15 \times 15 = \cdot 068 \times 225 = 15\cdot 3$ square inches, or between 15¼ and 15½ square inches.

After having determined the area of the ports, we may easily find the depth when the length is given, or, conversely, the length when the depth is given. Thus, suppose we know the length was 8 inches, then we find that the depth should be $15\cdot 3 \div 8 = 1\cdot 9125$ inches, or nearly 2 inches; or suppose we knew the depth was 2 inches, then we would find that the length was $15\cdot 3 \div 2 = 7\cdot 65$ inches, or nearly 7¾ inches.

Area of eduction ports.—The proper area for the eduction ports may be found from the following rule.

Rule.—To find the area of the eduction ports.—Multiply the square of the diameter of the cylinder in inches by ·128. The product is the area of the eduction ports in square inches.

Example.—Required the area of the eduction ports of a locomotive engine, when the diameter of the cylinders is 13 inches. In this example we have, according to the rule, area of eduction port $= \cdot 128 \times 13^2 = \cdot 128 \times 169 = 21\cdot 632$ inches, or between 21½ and 21¾ square inches.

Breadth of bridge between ports.—The breadth of the bridges between the eduction port and the induction ports is usually between ¾ inch and 1 inch.

Diameter of boiler.

Rule.—To find the inside diameter of the boiler.—Multiply the diameter of the cylinder in inches by 3·11. The product is the inside diameter of the boiler in inches.

Example.—Required the inside diameter of the boiler for a locomotive engine, the diameter of the cylinders being 15 inches.

In this example we have, according to the rule, inside diameter of boiler $= 15 \times 3{\cdot}11 = 46{\cdot}65$ inches, or about 3 feet $10\frac{5}{8}$ inches.

Length of boiler.—In the Northern and Eastern Counties Railway the length of the boiler is 8 feet, while in the North Midland Counties Railway, in the Great Western Railway, and in the Hartlepool Railway, the length of the boiler is $8\frac{1}{2}$ feet. In the Belgian railways the length of the boiler is 8 feet 2 inches. And in the Bordeaux and La Teste railway the length of the boiler is 8 feet 9 inches. In Stephenson's locomotive engines, the length of the boiler is between 11 and 12 feet. In this country the length is from 10 to 14 feet.

Diameter of steam dome inside.—It is obvious that the diameter of the steam dome may be varied considerably, according to circumstances; but the first indication is to make it large enough. It is usual, however, in practice, to proportion the diameter of the steam dome to the diameter of the cylinder; and there appears to be no great objection to this. The following rule will be found to give the diameter of the dome usually adopted in practice.

Rule.—To find the diameter of the steam dome.—Multiply the diameter of the cylinder in inches by 1·43. The product is the diameter of the dome in inches.

Height of steam dome.—The height of the steam dome may vary. Judging from practice, it appears that a uniform height of $2\frac{1}{2}$ feet would answer very well.

Diameter of safety-valve.—In practice the diameter of the safety-valve varies considerably. The following rule gives the diameter of the safety-valve usually adopted in practice.

Rule.—To find the diameter of the safety-valve.—Divide the diameter of the cylinder in inches by 4. The quotient is the diameter of the safety-valve in inches.

Example.—Required the diameter of the safety-valves for the boiler of a locomotive engine, the diameter of the cylinder being 13 inches. Here, according to the rule, diameter of safety-valve $= 13 \div 4 = 3\frac{1}{4}$ inches. A larger size, however, is preferable, as being less likely to stick.

Diameter of valve spindle.—The following rule will be found to give the correct diameter of the valve spindle. It is entirely founded on practice.

Rule.—To find the diameter of the valve spindle.—Multiply the diameter of the cylinder in inches by ·076. The product is the proper diameter of the valve spindle.

Example.—Required the diameter of the valve spindle for a locomotive engine whose cylinders' diameters are 13 inches.

In this example we have, according to the rule, diameter of valve spindle $= 13 \times {\cdot}076 = {\cdot}988$ inches, or very nearly 1 inch.

Diameter of chimney.—It is usual in practice to make the diameter of the chimney equal to the diameter of the cylinder. Thus, a locomotive engine whose cylinders' diameters are 15 inches would have the inside diameter of the chimney also 15 inches, or thereabouts. This rule has, at least, the merit of simplicity.

Area of fire-grate.—The following rule determines the area of the fire-grate usually given in practice. We may remark, that the area of the fire-grate in practice follows a more certain rule than any other part of the engine appears to do; but it is in all cases much too small, and occasions a great loss of power by the urging of the blast it renders necessary, and a rapid deterioration of the furnace plates from excessive heat. There is no good reason why the furnace should not be nearly as long as the boiler: it would then resemble the furnace of a marine boiler, and be as manageable.

Rule.—To find the area of fire-grate.—Multiply the diameter of the cylinder in inches by ·77. The product is the area of the fire-grate in superficial feet.

Example.—Required the area of the fire-grate of a locomotive engine, the diameters of the cylinders being 15 inches.

In this example we have, according to the rule, area of fire-grate $= {\cdot}77 \times 15 = 11{\cdot}55$ square feet, or about $11\frac{1}{2}$ square feet. Though this rule, however, represents the usual practice, the area of fire-grate should not be contingent upon the size of the cylinder, but upon the quantity of steam to be generated.

Area of heating surface.—In the construction of a locomotive engine, one great object is to obtain a boiler which will produce a sufficient quantity of steam with as little bulk and weight as possible. This object is admirably accomplished in the construction of the boiler of the locomotive engine. This little barrel of tubes generates more steam in an hour than was formerly raised from a boiler and fire occupying a considerable house. This favorable result is obtained simply by exposing the water to a greater amount of heating surface.

In the usual construction of the locomotive boiler, it is obvious that we can only consider four of the six faces of the inside fire-box as effective heating surface; viz., the crown of the box, and the three perpendicular sides. The circumferences of the tubes are also effective heating surface; so that the whole effective heating surface of a locomotive boiler may be considered to be the four faces of the inside fire-box, plus the sum of the surfaces of the tubes. Understanding this to be the effective heating surface, the following rule determines the average amount of heating surface usually given in practice.

Rule.—To find the effective heating surface.—Multiply the square of the diameter of the cylinder in inches by 5; divide the product by 2. The quotient is the area of the effective heating surface in square ft.

Example.—Required the effective heating surface of the boiler of a locomotive engine, the diameters of the cylinders being 15 inches.

In this example we have, according to the rule, effective heating surface $= 15^2 \times 5 \div 2 = 225 \times 5 \div 2 = 1125 \div 2 = 562\frac{1}{2}$ square feet.

According to the rule which we have given for the fire-grate, the area of the fire-grate for this boiler would be about $11\frac{1}{2}$ square feet. We may suppose, therefore, the area of the crown of the box to be 12 square feet. The area of the three perpendicular sides of the inside fire-box is usually three times the area of the crown; so that the effective heating surface of the fire-box is 48 square feet. Hence the heating surface of the tubes $= 526{\cdot}5 - 48 = 478{\cdot}5$ square feet. The inside diameters of the tubes are generally about $1\frac{3}{4}$ inches; and therefore the circumference of a section of these tubes is 5·4978 inches. Hence, supposing the tube to be $8\frac{1}{2}$ feet long, the surface of one $= 5{\cdot}4978 \times 8\frac{1}{2} \div 12 = {\cdot}45815 \times 8\frac{1}{2} = 3{\cdot}8943$ square feet. And, therefore, the number of tubes $= 478{\cdot}5 \div 3{\cdot}8943 = 123$ nearly.

Area of water-level.—This of course varies with the different circumstances of the boiler. The average area may be found from the following rule.

Rule.—To find the area of the water-level.—Multiply the diameter of the cylinder in inches by 2·08. The product is the area of the water-level in square feet.

Example.—Required the area of the water-level for a locomotive engine, whose cylinders' diameters are 14 inches.

In this case we have, according to the rule, area of water-level $= 14 \times 2{\cdot}08 = 29{\cdot}12$ square feet.

Cubical content of water in boiler.—This of course varies not only in different boilers, but also in the same boiler at different times. The following rule is supposed to give the average quantity of water in the boiler.

Rule.—To find the cubical content of the water in the boiler.—Multiply the square of the diameter of the cylinder in inches by 9; divide the product by 40. The quotient is the cubical content of the water in the boiler in cubic feet.

Example.—Required the average cubical content of the water in the boiler of a locomotive engine, the diameters of the cylinders being 14 inches.

In this example we have, according to the rule, cubical content of water $= 9 \times 14^2 \div 40 = 44{\cdot}1$ cubic feet.

Content of feed-pump.—In the locomotive engine, the feed-pump is generally attached to the cross-head, and consequently it has the same stroke as the piston. As we have mentioned before, the stroke of the locomotive engine is generally in practice 18 inches. Hence, assuming the stroke of the feed-pump to be constantly 18 inches, it only remains for us to determine the diameter of the ram. It may be found from the following rule.

Rule.—To find the diameter of the feed-pump ram.—Multiply the square of the diameter of the cylinder in inches by ·011. The product is the diameter of the ram in inches.

Example.—Required the diameter of the ram for the feed-pump for a locomotive engine whose diameter of cylinder is 14 inches.

In this example we have, according to the rule, diameter of ram $= {\cdot}011 \times 14^2 = {\cdot}011 \times 196 = 2{\cdot}156$ inches, or between 2 and $2\frac{1}{4}$ inches.

Cubical content of steam room.—The quantity of steam in the boiler varies not only for different boilers, but even for the same boiler in different circumstances. But when the locomotive is in motion, there is usually a certain proportion of the boiler filled with the steam. Including the dome and the steam-pipe, the content of the steam room will be found usually to be somewhat less than the cubical content of the water. But as it is desirable that it should be increased, we give the following rule.

Rule.—To find the cubical content of the steam room.—Multiply the square of the diameter of the cylinder in inches by 9; divide the product by 40. The quotient is the cubical content of the steam room in cubic feet.

Example.—Required the cubical content of the steam room in a locomotive boiler, the diameters of the cylinders being 12 inches.

In this example we have, according to the rule, cubical content of steam room $= 9 \times 12^2 \div 40 = 9 \times 144 \div 40 = 32{\cdot}4$ cubic feet.

Cubical content of inside fire-box above fire-bars.—The following rule determines the cubical content of fire-box usually given in practice.

Rule.—To find the cubical content of inside fire-box above fire-bars.—Divide the square of the diameter of the cylinder in inches by 4. The quotient is the content of the inside fire-box above fire-bars in cubic feet.

Example.—Required the content of inside fire-box above fire-bars in a locomotive engine, when the diameters of the cylinders are each 15 inches.

In this example we have, according to the rule, content of inside fire-box above fire-bars $= 15^2 \div 4 = 225 \div 4 = 56\frac{1}{4}$ cubic feet.

Thickness of the plates of boiler.—In general the thickness of the plates of the locomotive boiler is 9-32 inch, or No. 3 wire gage.

Inside diameter of steam-pipe.—The diameter usually given to the steam-pipe of the locomotive engine may be found from the following rule.

Rule.—To find the diameter of the steam-pipe of the locomotive engine.—Multiply the square of the diameter of the cylinder in inches by ·03. The product is the diameter of the steam-pipe in inches.

Example.—Required the diameter of the steam-pipe of a locomotive engine, the diameter of the

cylinder being 13 inches. Here, according to the rule, diameter of steam-pipe $= \cdot 03 \times 13^2 = \cdot 03 \times 169 = 5 \cdot 07$ inches; or a very little more than 5 inches. The steam-pipe is usually made too small in engines intended for high speeds.

Diameter of branch steam-pipes.—The following rule gives the usual diameter of the branch steam-pipe for locomotive engines.

Rule.—To find the diameter of the branch steam-pipe for the locomotive engine.—Multiply the square of the diameter of the cylinder in inches by ·021. The product is the diameter of the branch steam-pipe for the locomotive engine in inches.

Example.—Required the diameter of the branch steam-pipes for a locomotive engine, when the cylinders' diameter is 15 inches. Here, according to the rule, diameter of branch pipe $= \cdot 021 \times 15^2 = \cdot 021 \times 225 = 4 \cdot 725$ inches, or about $4\frac{3}{4}$ inches.

Diameter of top of blast-pipe.—The diameter of the top of the blast-pipe may be found from the following rule.

Rule.—To find the diameter of the top of the blast-pipe.—Multiply the square of the diameter of the cylinder in inches by ·017. The product is the diameter of the top of the blast-pipe in inches.

Example.—The diameter of a locomotive engine is 13 inches; required the diameter of the blast-pipe at top. Here, according to the rule, diameter of blast-pipe at top $= \cdot 017 \times 13^2 = \cdot 017 \times 169 = 2 \cdot 873$ inches, or between $2\frac{3}{4}$ and 3 inches; but the variable exhaust is now generally used.

Diameter of feed-pipes.—There appear to be no theoretical considerations which would lead us to determine exactly the proper size of the feed-pipes. Judging from practice, however, the following rule will be found to give the proper dimensions.

Rule.—To find the diameter of the feed-pipes.—Multiply the diameter of the cylinder in inches by ·141. The product is the proper diameter of the feed-pipes.

Example.—Required the diameter of the feed-pipes for a locomotive engine, the diameter of the cylinder being 15 inches.

In this example we have, according to the rule, diameter of feed-pipe $= 15 \times \cdot 141 = 2 \cdot 115$ inches, or between 2 and $2\frac{1}{4}$ inches.

Diameter of piston-rod.—The diameter of the piston-rod for the locomotive engine is usually about one-seventh the diameter of the cylinder. Therefore,

Rule.—To find the diameter of the piston-rod for the locomotive engine.—Divide the diameter of the cylinder in inches by 7. The quotient is the diameter of the piston-rod in inches.

Example.—The diameter of the cylinder of a locomotive engine is 15 inches, required the diameter of the piston-rod. Here, according to the rule, diameter of piston-rod $= 15 \div 7 = 2\frac{1}{7}$ inches.

Thickness of piston.—The thickness of the piston in locomotive engines is usually about two-sevenths of the diameter of the cylinder. Therefore,

Rule.—To find the thickness of the piston in the locomotive engine.—Multiply the diameter of the cylinder in inches by 2; divide the product by 7. The quotient is the thickness of the piston in inches.

Example.—The diameter of the cylinder of a locomotive engine is 14 inches, required the thickness of the piston. Here, according to the rule, thickness of piston $= 2 \times 14 \div 7 = 4$ inches.

Diameter of connecting-rods at middle.—The following rule gives the diameter of the connecting-rod at middle. The rule is entirely founded on practice.

Rule.—To find the diameter of the connecting-rod at middle of the locomotive engine.—Multiply the diameter of the cylinder in inches by ·21. The product is the diameter of the connecting-rod at middle in inches.

Example.—Required the diameter of the connecting-rods at middle for a locomotive engine, the diameter of the cylinders being 12 inches.

For this example we have, according to the rule, diameter of connecting-rods at middle $= 12 \times \cdot 21 = 2 \cdot 52$ inches, or $2\frac{1}{2}$ inches.

Diameter of ball on cross-head spindle.—The diameter of the ball on the cross-head spindle may be found from the following rule.

Rule.—To find the diameter of the ball on cross-head spindle of a locomotive engine.—Multiply the diameter of the cylinder in inches by ·23. The product is the diameter of the ball on the cross-head spindle.

Example.—Required the diameter of the ball on the cross-head spindle of a locomotive engine, when the diameter of the cylinder is 15 inches. Here, according to the rule, diameter of ball $= \cdot 23 \times 15 = 3 \cdot 45$ inches, or nearly $3\frac{1}{2}$ inches.

Diameter of the inside bearings of the crank-axle.—It is obvious that the inside bearings of the crank-axle of the locomotive engine correspond to the paddle-shaft journal of the marine engine, and to the fly-wheel shaft journal of the land engine. We may conclude, therefore, that the proper diameter of these bearings ought to depend jointly upon the length of the stroke and the diameter of the cylinder. In the locomotive engine the stroke is usually 18 inches, so that we may consider that the diameter of the bearing depends solely upon the diameter of the cylinder. The following rule will give the diameter of the inside bearing.

Rule.—To find the diameter of the inside bearing for the locomotive engine.—Extract the cube root of the square of the diameter of the cylinder in inches; multiply the result by ·96. The product is the proper diameter of the inside bearing of the crank-axle for the locomotive engine.

Diameter of plain part of crank-axle.—It is usual to make the plain part of crank-axle of the same sectional area as the inside bearings.

Rule.—To determine the diameter of the plain part of crank-axle for the locomotive engine.—Extract the cube root of the square of the diameter of the cylinder in inches; multiply the result by ·96. The product is the proper diameter of the plain part of the crank-axle of the locomotive engine in inches.

Diameter of the outside bearings of the crank-axle.—The crank-axle, in addition to resting upon the inside bearings, is sometimes also made to rest partly upon outside bearings. These outside bearings are added only for the sake of steadiness, and they do not need to be so strong as the inside bearings. The proper size of the diameter of these bearings may be found from the following rule.

Rule.—To find the diameter of outside bearings for the locomotive engine.—Multiply the square of the diameter of the cylinders in inches by ·396; extract the cube root of the product. The result is the diameter of the outside bearings in inches.

Diameter of crank-pin.—The following rule gives the proper diameter of the crank-pin. It is obvious that the crank-pin of the locomotive engine is not altogether analogous to the crank-pin of the marine or land engine, and, like them, ought to depend upon the diameter of the cylinder, as it is usually formed out of the solid axle.

Rule.—To find the diameter of the crank-pin for the locomotive engine.—Multiply the diameter of the cylinder in inches by ·404. The product is the diameter of the crank-pin in inches.

Example.—Required the diameter of the crank-pin of a locomotive engine whose cylinders' diameters are 15 inches.

In this example we have, according to the rule, diameter of crank-pin $= 15 \times {\cdot}404 = 6{\cdot}06$ inches, or about 6 inches.

Length of crank-pin.—The length of the crank-pin usually given in practice may be found from the following rule.

Rule.—To find the length of the crank-pin.—Multiply the diameter of the cylinder in inches by ·233. The product is the length of the crank-pins in inches.

The part of the crank-axle answering to the crank-pin is usually rounded very much at the corners, both to give additional strength, and to prevent side play.

These, then, are the chief dimensions of locomotive engines, according to the practice most generally followed. The establishment of express trains and the general exigencies of steam locomotion are daily introducing innovations, the effect of which is to make the engines of greater size and power; but it cannot be said that a plan of locomotive engine has yet been contrived that is free from grave objections. The most material of these defects is the necessity that yet exists of expending a large proportion of the power in the production of a draft; and this evil is traceable to the inadequate area of the fire-grate, which makes an enormous rush of air through the fire necessary to accomplish the combustion of the fuel requisite for the production of the steam. To gain a sufficient area of fire-grate an entirely new arrangement of engine must be adopted; the furnace must be greatly lengthened, and perhaps it may be found that short upright tubes may be introduced with advantage. Upright tubes have been found to be more effectual in raising steam than horizontal tubes; but the tube-plate in the case of upright tubes would be more liable to burn.

We here give the preceding rules in formulæ, in the belief that those well acquainted with algebraic symbols prefer to have a rule expressed as a formula, as they can thus see at once the different operations to be performed. In the following formulas we denote the diameter of the cylinder in inches by D.

Locomotive engine.—Parts of the cylinder.

Area of induction-ports, in square inches $= {\cdot}068 \times D^2$.
Area of eduction-ports, in square inches $= {\cdot}128 \times D^2$.
Breadth of bridge between ports between ¾ inch and 1 inch.

Locomotive engine.—Parts of boiler

Diameter of boiler, in inches $= 3{\cdot}11 \times D$.
Length of boiler between 8 feet and 12 feet.
Diameter of steam dome inside, in inches $= 1{\cdot}43 \times D$.
Height of steam dome $= 2\frac{1}{2}$ feet.
Diameter of safety-valve, in inches $= D \div 4$.
Diameter of valve-spindle, in inches $= {\cdot}076 \times D$.
Diameter of chimney, in inches $= D$.
Area of fire-grate, in square feet $= {\cdot}77 \times D$.
Area of heating-surface, in square feet $= 5 \times D^2 \div 2$.
Area of water-level, in square feet $= 2{\cdot}08 \times D$.
Cubical content of water in boiler, in cubic feet $= 9 \times D^2 \div 40$.
Diameter of feed-pump ram in inches $= {\cdot}011 \times D^2$.
Cubical content of steam room, in cubic feet $= 9 \times D^2 \div 40$.
Cubical content of inside fire-box above fire-bars, in cubic feet $= D^2 \div 4$.
Thickness of the plates of boiler $= \frac{3}{8}$ inch.

Locomotive engine.—Dimensions of several pipes.

Inside diameter of steam-pipe, in inches $= {\cdot}03 \times D^2$.
Inside diameter of branch steam-pipe, in inches $= {\cdot}021 \times D^2$.
Inside diameter of the top of blast-pipe $= {\cdot}017 \times D^2$.
Inside diameter of the feed-pipes $= {\cdot}141 \times D$.

Locomotive engines.—Dimensions of several moving parts.

Diameter of piston-rod, in inches $= D \div 7$.
Thickness of piston, in inches $= 2\,D \div 7$.
Diameter of connecting-rods at middle, in inches $= \cdot 21 \times D$.
Diameter of the ball on cross-head spindle, in inches $= \cdot 23 \times D$.
Diameter of the inside bearings of the crank-axle, in inches $= \cdot 96 \times \sqrt[3]{D^2}$.
Diameter of the plain part of crank-axle, in inches $= \cdot 96 \times \sqrt[3]{D^2}$.
Diameter of the outside bearings of the crank-axle, in inches $= \sqrt[3]{\cdot 396 \times D^2}$.
Diameter of crank-pin, in inches $= \cdot 404 \times D$.
Length of crank-pin, in inches $= \cdot 233 \times D$.

Expedients for regulating the velocity, and ascertaining the state and effective power of the engine.—In most engines yet invented for developing mechanical effect from steam, there are great irregularities in the velocity of the engine unless some contrivance be added to equalize the action of the steam. In the land engine, and in the marine engine, the inequalities of velocity may be considered to proceed from two sources; one, the unequal action of the mechanism of the engine itself, and the other the unequal resistances which the engine has to overcome. The piston does not move with a uniform velocity up and down the cylinder. The velocity is greatest at half stroke, and gradually decreases towards the end of the stroke till it stops altogether, and finally returns in the opposite direction. When it is said that the velocity of the piston is so many feet per minute, it is at once inferred that this can only be the mean velocity, and that at the middle of the stroke the piston moves faster, and at the termination slower, than the specified velocity. But even if the piston were to move uniformly, the intervention of the crank would introduce irregularities into the velocity of the engine. The crank is certainly the best constructive expedient yet devised for deriving a rotary motion from the reciprocating motion of the piston; but, with all its advantages, it has the defect of not transmitting uniformly the pressure and velocity of the engine. Let it not be inferred from this statement that we intend to show the least favor to the exploded notion of the crank absorbing some of the power or mechanical effect of the steam. The crank, like every other piece of machinery, transmits at every instant all the mechanical effect communicated to it; so that the only way in which we can suppose it to have an appetite for devouring power is by taking into consideration the friction of the parts connected with it. But this is not inconsistent with our statement that the crank does not transmit the pressure and velocity of the piston uniformly. The mechanical effect transmitted by the crank at any instant is measured by the product of the effective pressure on the crank into its velocity at that instant; and this is exactly equal to the mechanical effect generated at the piston at the same instant, as measured by the product of the pressure on the piston into its velocity. But then the velocity of the crank does not always bear the same proportion to the velocity of the piston, nor does the effective pressure on the crank always bear the same proportion to the pressure on the piston. The products are constantly equal, but the proportions of the elements constantly change; and the effect of the intervention of the crank, if unredressed, would be to cause the velocity of the machinery driven by the engine to undergo inconvenient fluctuations.

These irregularities proceeding from the internal mechanism of the engine itself would leave the mean velocity unaffected. Supposing the amount of steam supplied, and the amount of resistance to be overcome, to remain constant, then, although the velocity would be different for different positions of the crank, still the average velocity throughout a whole revolution would remain constant. If, however, the amount of resistance to be overcome be changed, the average velocity will also change, unless the supply of steam be modified so as to suit the exigency. We may see the great variation of resistance which a marine engine has to sustain in a storm. Sometimes the paddle-board is deeply immersed in the wave—at other times it is almost completely out of the water; and in these circumstances it is obvious that the average velocity of the paddle-shaft will vary. Analogous variations are experienced in most of the applications of the land engine. If a land engine be employed to drive the machinery of a cotton-mill, it will have to impart motion to all the spinning-frames in that mill. The operation of one or more of these may from time to time be suspended, and consequently the moving power will be relieved from a corresponding amount of resistance, and again the spinning-frames offer different resistances at different times. These circumstances, it is obvious, must effect the mean velocity of the engine, unless some contrivance be added to modify the supply of steam so as to correspond to the amount of resistance to be overcome. If, under such circumstances, the energy of the moving power remains the same, the velocity with which the machinery will be driven must be subject to variation, being increased whenever the operation of any portion of the machines usually driven by it is suspended; and, on the other hand, diminished when any increased number of machines are brought into operation. In fine, the speed will vary nearly in the inverse proportion of the load driven, increasing as the load is diminished, and *vice versa*.

Now in most of the applications of the steam-engine, irregularity of velocity is considered to be a great evil, and every exertion is made to lessen it as much as possible. Indeed, in all applications of machinery it is desirable, all other things being equal, to have the motion uniform. On this Tredgold remarks, very justly, "An equable motion is desirable in almost every kind of machine, it being strained much more by an irregular desultory one, as well as the fabric that supports it, than when the motion is equable. The strength of the machine must be adapted to the greatest strains that occur; but the quantity of work done is equivalent to the mean action only, and more is not performed by a desultory motion than by one at a mean rate, and uniform." But uniformity of velocity is more sought after in some of the applications of the steam-engine than in others. In the marine engine and the locomotive engine all the requisite uniformity is obtained by attaching two engines to the main shaft, and so adjusting them that the irregularities of the one engine partly counteract the irregularities of the other.

The plan does not ensure perfect uniformity, but it approaches to it as far as particular circumstances seem to require. In these engines no provision is made that the supply of steam should adapt itself to the amount of resistance to be overcome. Again, in the common pumping-engine, there is not so much urgent necessity for uniformity of motion as in most other applications of the land engine. Indeed, judging from practice, we may infer that the advantage to be gained by a greater uniformity in the velocity of the pumping-engine is not sufficiently great to compensate for the increased expense incurred in providing and repairing a mechanism for redressing its inequalities. However, in many of the other applications of the land engine, uniformity of velocity is the great object aimed at, and provision is made for approximating to it as closely as possible.

We have pointed out two sources of irregularity of velocity; one the peculiar internal mechanism of the engine itself, and the other the unequal resistances which it has to overcome. We proceed now to mention in detail the several remedies that have been proposed for redressing these inequalities; and first we proceed to mention those remedies which have been proposed for redressing the inequalities arising from the peculiar mechanism of the engine itself.

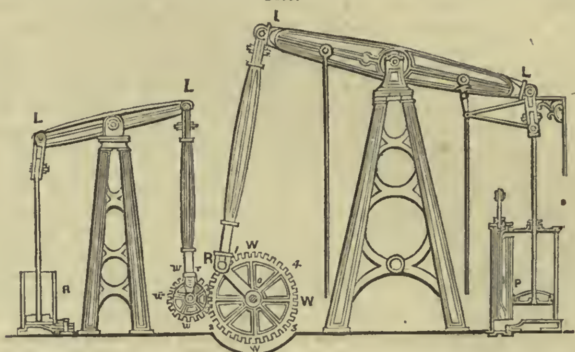
Remedies for redressing the inequalities arising from the mechanism of the engine itself.—We have already mentioned, that in the marine engine and locomotive engine an approximation to uniformity of velocity and uniformity of pressure is obtained by putting two engines upon the same shaft, and so adjusting them that when the piston of the one engine is at its maximum velocity, the piston of the other is at its minimum, and *vice versa.* This is effected by placing the cranks at right angles to one another. The velocity obtained in this way is more nearly uniform than when only one engine is used, but, unless assisted by a fly-wheel, the irregularities would be too great for many of the nice applications of the modern steam-engine. Another objection to this plan is, that it requires two engines, and thus takes up more room, and offers more constructive difficulties, than if the requisite power were obtained from one engine only. These objections are to a certain extent obviated by an ingenious plan first proposed by Mr. Mark Isambard Brunel, and for which he obtained a patent in 1823. In his plan, instead of using two cranks, two cylinders are employed to give motion to the same crank This is effected by inclining the two cylinders to one another at an angle of about 90°, and causing them to act upon the same axle by means of their connecting-rods. The frame of the engine is of the form of an isosceles triangle. The working cylinders rest upon the inclined sides, and the main shaft upon the apex of the triangle. The piston-rod is preserved in its rectilineal course by metal rollers running upon guide-plates, which act a similar part to the vertical guides in the common direct-action engine. Mr. Brunel states that the axis of the cylinders should be inclined to one another at an angle of 102°; having, as he says, found that angle to be preferable to all others for transmitting a rotary motion to the axle from the reciprocating motion of the pistons: but there seems to be no theoretical considerations which would lead us to prefer an angle of 102° to an angle of 90°, except that the weight of the pistons and their connections presses only in a downward direction. Underneath each of the working cylinders is placed a small cylinder containing the valve. The valves are wrought by eccentrics from the main shaft, and the steam is alternately admitted into one end of the working cylinder, and a passage opened for its escape at the other, as is the usual arrangement. From this form of construction it follows, that when the piston of one of the cylinders is at half-stroke, the piston of the other is at the termination of its stroke, or nearly so; and thus the irregularities of the one cylinder partly counteract the irregularities of the other. It is obvious, however, that this engine, whatever may be its peculiar advantages in other respects, will fail in obtaining any greater regularity of velocity than is obtained in the more usual construction, by placing two marine engines or two locomotive engines upon the same shaft—a motion which of itself is too irregular for many of the modern applications of the steam-engine.

When the expansive principle is employed in an engine, it involves the condition of a variation in the intensity of the moving power. If the steam acts with a uniform energy on the piston as long as the supply from the boiler continues, so soon as that supply is stopped by closing the steam-valve, the steam contained in the cylinder will fill a gradually increasing volume by the motion of the piston, and consequently will act above the piston with a gradually decreasing energy. Now, if the resistance to the moving power be not subject to a variation corresponding exactly to this variation in the moving power, the result will be that the motion will cease to be uniform. For if the momentum of the moving power at any part of the stroke be greater than the resistance, the motion of the machinery will be accelerated; and if it be less, the motion of the machinery will be retarded. Hence the application of the expansive principle will introduce irregularities peculiar to itself. In the patent which Watt took out for the application of the expansive principle, he specified several expedients for approximating to a uniform effect upon a uniform resistance, notwithstanding the variation of the energy of the power which necessarily attended the expansion of the steam. One method consisted in causing the moving force, when acting with the greatest energy, to impart momentum to a mass of inert matter, which should be made to restore the same force when the moving power was more enfeebled. Another expedient consisted in causing the moving power, when acting with greatest energy, to lift a weight hung considerably above the centre of the beam which should resist the ascent of the piston at the beginning of the stroke, but aid its motion as soon as the beam passed the horizontal line, when the weight, like a tumbler, would pass its centre of gravity. He also proposed to make the piston act on a lever, which should have an arm of variable length, and so regulated, that when the momentum of the moving force increased or diminished, the length of the arm diminished or increased in the same proportion. This last expedient had been already applied in mechanics for the purpose of equalizing a varying power, and a familiar example of its action occurs in the internal mechanism of a watch. When a watch is newly wound up, the force of the spring is much greater than when the watch is nearly run down; so that if the force of the spring always acted at the same leverage, a very unequal velocity would be produced. The irregularity, however, is counteracted by the varying diameters of the grooves of the fusee, on which the force of the spring, through the intervention of the chain, acts. As the watch goes down, the

main-spring relaxes, and its force diminishes; but then the chain acts upon a wheel or circle having a diameter increased in the same proportion as the strength of the spring is diminished. This expedient, however, has never been successfully employed to regulate the action of the moving power of the steam-engine; and it does not appear to be as practicable a scheme as that of hanging a weight above the centre of the beam.

The following ingenious expedient for equalizing the action of the steam in the engine, was first suggested by Mr. Buckle, of Soho, and constructed by him for Mr. Lucy, of Birmingham. It acts upon the principle of causing the engine to drag up a piston against the pressure of the atmosphere when the energy of the moving power is above the average; the power thus consumed being returned to the engine by the atmosphere forcing down the piston when the energy of the moving power is below the average, Fig. 1469. The manner in which this is accomplished may be easily understood from the accompanying figure. P represents the piston in the cylinder, L L the great beam, L R the connecting-rod, R O the crank, and R W W W a toothed wheel carried round by the crank. These are all the same as in the common steam-engine. There is added *r w w w*, a smaller wheel, whose diameter is only one-half that of the larger, and consequently it has only one-half the number of teeth. The small wheel will obviously perform a half revolution whilst the large wheel performs a quarter revolution. *l l* is a second

1469.



lever, driven by the crank of the small wheel, to which it is attached by means of its connecting-rod. The piston-rod *l* H is attached to the small lever *l l*, carrying with it a piston from top to bottom of an open cylinder H. At the points marked 1, 2, 3, 4, the circumference of the great wheel is supposed to be divided into four equal quadrants. Suppose now that the figure represents the state of the engine when the piston is ascending. Whilst the crank moves from its present position to the position corresponding to 2, the small wheel will have performed a semi-revolution, and the piston H will have ascended to the top of the open cylinder, leaving a vacuum behind it. The piston H has been dragged up against the pressure of the atmosphere, and this has consumed so much of the power of the engine. This power, however, is not lost—it is only lent; for while the crank moves from the position 2 to the position 3, the pressure of the air forces down the piston, and then the mechanical power is given back to the large wheel. Again, whilst the crank moves from the position 3 to the position 4, the piston H has to be dragged up to the top of the cylinder. Finally, whilst the crank moves from the position 4 to the position 1, the pressure of the air forces down the piston of the open cylinder. Thus all the power consumed in dragging up the piston against the pressure of the atmosphere, whilst the crank moves from 1 to 2 and from 3 to 4, is faithfully given out to the wheel whilst the crank moves from 2 to 3 and from 4 to 1. By this arrangement the engine is made to lay up, as it were, a store of power when the moving force is acting with greatest energy, and this store is employed to assist it when the moving force is acting with least energy. The pressure of the atmosphere is very adroitly converted into a sort of reservoir, in which is deposited the surplus power generated while the crank moves from 1 to 2, and from 3 to 4, to be withdrawn in order to supply the deficiency whilst the crank moves from 2 to 3 and from 4 to 1. Let A denote the number of square inches in the piston H, and h the number of feet in the diameter of the small wheel; then the power necessary to drag the small piston from the bottom of the cylinder to the top, exclusive of the friction, is represented by a mechanical effect of $15 \times A \times h$ lb. raised one foot high. Hence, the total effect of this pneumatic pump is equivalent to causing the engine to raise $15 \times A \times h$ lb. one foot high whilst the crank is passing the quadrantal points, and allowing that weight to fall whilst the crank is passing the line of the centres. At the first consideration we may perhaps infer that there would be a sudden change of velocity and pressure when the small piston had arrived at the top or the bottom of its stroke; but a little more attention will convince us that the change is gradually introduced by the peculiar relation of the wheels to one another. In the position represented in the figure, the crank moves a certain distance past position 1 without raising the piston to any great extent. As the crank descends to the quadrantal point, in which position most power is generated, the crank of the small wheel descends to its quadrantal point, in which position the pressure of the atmosphere on the piston H, offers the greatest resistance to the motion of the wheel. After the large crank has passed its quadrantal point, the energy of the moving power begins to lessen, and at the same time, the small crank having passed its quadrantal point, the motion of the small wheel is less retarded by the pressure of the atmosphere on the piston H. When the large crank approaches to the position 2, the small crank approaches to the lowest part of its revolution, where the pressure of the atmosphere on the piston H, offers little opposition to the motion of the small wheel.

It is unnecessary to examine the action of the pump throughout the whole revolution of the wheel, as it would be only a repetition of the process for a quadrant. But we see that, by the peculiar connection of the wheel, the pressure of the atmosphere acts at one time as an accelerating force, at another as a retarding force; that the change is not abrupt, but gradual; that it acts most efficiently as a retarding force at the very moment that the energy of the moving force is greatest, viz., when the large crank is passing the quadrantal points; and finally, it acts most efficiently as an accelerating force at the very moment that the energy of the moving force is least, viz., when the crank is passing the line of the centres. In fact, this pneumatic equalizer approaches more closely to theoretical perfection, than any expedient ever proposed for equalizing the action of the engine. It may easily be shown that the equalization of the effective pressure on the shafts is more efficient than that obtained by using a pair of engines, and certainly it is much less complicated and expensive. The superiority is still more manifest when we consider the regularity of velocity which it in practice has been known to introduce. The principal objection against the expedient is, that the toothed wheels are very bad constructive expedients, as they cause considerable friction, and the teeth are apt to break and to throw the whole into disarrangement.

Several ingenious expedients have been proposed for enabling one shaft performing a certain number of revolutions per minute to drive another shaft so as to make more revolutions per minute without connecting them together by tooth geering; but it would take up too much of our space to describe them here. We may only refer to one which is applied in Smith's direct-action engine. This expedient enables the main shaft to drive a second shaft with a double velocity; the very thing which is required for Buckle's pneumatic equalizer. We may remark that expedients for multiplying velocity are invested with additional interest at present, from the introduction of the screw propeller. Before a sufficiency of resistance can be obtained from the screw propeller, it must be made to perform more revolutions per minute than the paddle-shaft, in the more common construction.

To demonstrate the practical efficiency of Buckle's equalizer, we may instance the great success which has attended its application at a Birmingham flour-mill. So perfect was the action of this mechanism that the fly-wheel had been wholly removed, and the engine and the whole mill-work were moving in the most smooth and effective manner. It was found that the change enabled them to give all the grinding stones a greater velocity than formerly, so that the quantity ground was greater, in the proportion of 56 to 52, and the quantity of the finest or first flour, from the same wheat, was likewise much increased; so that, both by quantity and quality, the owner of the mill was now able to *command the market*. The same motion has subsequently been applied to cotton-mills with perfect success, the quality and the quantity of yarn produced being much improved.

The last expedient for equalizing the action of the steam which we shall notice, is that known as the fly-wheel. The fly-wheel derives all its efficacy as an equalizer of the action of the steam from the principle, that a large mass of matter offers great resistance to a change of motion. In a common double-action engine, the steam loses all energy as a moving power for driving the machinery when the crank is passing the line of the centres, and a person not familiar with the laws of matter might conclude that the engine would come to a stand-still, unless some moving force was applied at these critical positions. It is well known, however, that the momentum of the moving parts of the machinery will supply a force sufficient to force the crank over the centre, although with a diminished velocity. The momentum of the moving parts acts therefore to a certain extent as a regulator of the action of the steam, and the addition of the fly-wheel only promotes regularity of velocity in so far as it increases this momentum. The moving force of a body in motion is estimated by the product of its mass into its velocity. If, therefore, we wish to regulate the velocity of an engine, by increasing the momentum of its moving parts, we have only to connect with it some large mass that it moves with great velocity. Such a mass is the fly-wheel: it is made of large diameter, so that its rim revolves with great rapidity; and the rim is made of great weight, it being generally constructed of cast-iron. It is obvious that the same amount of momentum may be obtained by other forms of construction; but the wheel possesses three advantages peculiar to itself, which entitle it to the preference: it consumes no power by friction; it suffers but little resistance to its motion from the air; and, finally, it can be so exactly poised on its axis as to cause little strain on the machinery.

When the piston is at half-stroke, the energy of the moving force is at its maximum, so that at this time more mechanical effect is generated than the usual resistance can appropriate. The surplus mechanical effect is expended in quickening the velocity of all the moving parts of the machinery. But the greater the mass of a moving body, the more opposition does it offer to a change of motion; so that the large mass of the fly-wheel absorbs the surplus mechanical effect without any great change of velocity. As the crank approaches the dead points, the effect of the moving power upon the axle and the wheel is gradually enfeebled. The defect can only be supplied by abstracting some of the momentum of the moving parts, and in these circumstances the large mass of the fly-wheel can give out the sufficient quantity of momentum without any considerable change of velocity. The mass of the fly-wheel is thus converted into a reservoir for receiving the surplus power at one time, and giving it out at another. It is obvious, however, that the equalization of the motion produced by the fly-wheel is partial, and can never be theoretically perfect. The fly-wheel acts as a receptacle of momentum, and as matter can only receive momentum or give out momentum by a change of velocity, its agency as an equalizer presupposes a slight change in the velocity of all the machinery. The motion of revolution received by the main shaft is always subject to a variation corresponding to the amount of change of momentum in the great mass of the fly-wheel sufficient to extricate the crank twice in every revolution from its critical position while passing the line of centres; but this change can be rendered smaller and smaller by increasing the weight and magnitude of the fly-wheel. Buckle's Pneumatic Equalizer acts upon the principle of increasing or diminishing the resistance according as the energy of the moving force increases or diminishes; the fly-wheel, on the other hand, acts upon the principle of increasing the momentum of the moving parts of the machinery, so that when the energy of the moving force is greater

or less than the resistance, the surplus may be absorbed or the defect supplied without any sensible change in the motion of the whole. The former is capable of theoretical perfection; the latter must necessarily fall short of that perfection, though it may be made sufficiently near it for practicable purposes.

Fly-wheels are sometimes employed for other purposes than merely regulating the velocity of the steam-engine. Whenever the employment of an engine is such that an enormous force is required to act only for short times, such as when it is employed for rolling iron, or for stamping coins, then an enormous fly-wheel is attached to the engine, which absorbs the power generated when the resistance is removed, and gives it all the force at once at the proper moment. In these cases, the mass of the fly wheel rim is generally much greater than when the fly-wheel is only employed to regulate the velocity in order that the momenta may be accumulated without inconveniently increasing the velocity. In some cases the energy of the fly-wheel would be thirteen times greater than what the proportions given by our rule would make it. Fly-wheels moving at a great velocity should always have malleable iron arms, and the ring should be cast in a piece, and may be hooped with malleable iron with advantage.

Expedients for redressing the inequalities of velocity arising from the variation of resistance which the engine has to overcome.—By the expedients which we have mentioned for equalizing the velocity of the engine, the motion imparted to the main shaft will approximate to uniformity, provided that the moving power of the engine be always proportionate to the load which the engine has to drive. But it is obvious that in the general application of the steam-engine to the purposes of manufacture, provision must be made for a considerable variation of the amount of resistance. If, while the amount of resistance was changed, the energy of the moving power remained the same, then the velocity would also change, increasing as the resistance diminished, and diminishing as the resistance increased. It is obvious that an expedient for redressing the inequalities arising from this source may act upon the principle of regulating the supply of steam from the boiler. The elastic force of the steam is the moving agent of the whole machine; so that if we wish to keep the mean velocity constant, we must regulate the supply of steam to the amount of resistance to be overcome. The simplest contrivance for this purpose is the throttle-valve; so called from its agency in cutting off the supply of steam by throttling it in the steam-pipe. It consists of an axis placed across the steam-pipe so as to form the diameter of a section of the pipe, and on this axis is fixed a thin circular disk of nearly the same diameter as the inside diameter of the steam-pipe; so that when the axis is turned to a certain position, the supply of steam is cut off altogether. On one end of the axis is placed a short lever or handle, by which it can be turned in either direction. When the handle is turned so that the plane of the disk is nearly at right angles to the direction of the steam-pipe, the passage within the pipe is closed altogether, and no steam can find admission to the cylinder. On the other hand, when the handle is turned about a fourth of a complete revolution from this position, the plane of the circular disk will then be in the direction of the length of the pipe, so as to offer little or no opposition to the passage of the steam. By turning the handle to any other angle, the disk may be made to offer any required degree of opposition to the passage of the steam. The form of the valve is obviously such, that, if constructed accurately, the pressure of the steam in passing from the boiler will have no tendency to change any given position of the valve. If constructed accurately, the quantity of surface on both sides of the axis is equal, and therefore the pressure of the steam balances itself on the axis, so that it can have no tendency either to change the valve from its existing position, or to oppose the effect of a pressure upon the handle. Any slight inaccuracy in the construction of the valve, which would give the steam a capability of changing its position, would be counteracted by the friction of the valve on its axis.

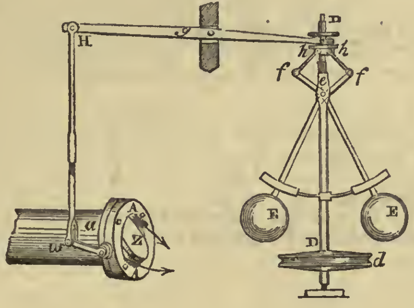
By this expedient the variations of the velocity of the engine, consequent upon the inequalities of resistance which the engine has to overcome, may be remedied. If the load on the engine be lightened, then, the supply of the steam continuing the same, the motion will be immediately accelerated; but the tendency will be counteracted if the attendant workman turn round the handle, so as partially to close the valve. If, on the other hand, the load on the engine be increased, then, the supply of the steam continuing the same, the motion will be immediately retarded. To counteract this, the attendant workman must turn round the valve, so as to admit a greater supply of steam. By the adoption of these means the mean velocity of the engine would be rendered uniform, provided the vigilance of the attendant workman were sufficient for the due management of the valve, and provided that the evaporating power of the boiler continued in sufficient activity to supply the greatest amount of steam which would ever be necessary for the maintenance of the mean velocity when the valve was fully open.

For some purposes engines are thus regulated by hand at the pleasure of the attendant workman. In general, however, the proper manipulation of the handle is impracticable with any degree of vigilance and skill which could be obtained from the person employed to attend the engine. Before the steam-engine could be employed in those cases where great uniformity of velocity is required, it was necessary that means should be found for enabling the engine itself properly to manipulate the valve without any care or attention on the part of the attendant workman.

The governor.—In the mechanism of the governor as represented in Fig. 1470, E E represent two heavy balls of iron, which are suspended from the point e by suitable arms. These bars cross one another at e, forming a joint there, and are continued to f. At f these bars are joined by pivots to other bars $f\,h$, which last fit into a ring or collar of metal at F, placed on the upright spindle, so as to be capable of a motion upwards and downwards. The lever F G H rests upon a bar at G as fulcrum, and is connected to the ring of metal at F by means of a forked end interposed between two collars on the sliding piece. In this species of connection it is obvious that the ring of metal may revolve with the spindle without moving the lever, but that it cannot move upwards or downwards on the spindle without at the same time depressing or raising the remote extremity, H, of the lever. The bars E $e\,f$ pass through slits in a metallic arch, which is firmly fixed to the upright spindle, so that the balls, the arms, and the spindle must all revolve at the same time. If, now, the spindle be made in any manner whatever to revolve with a certain velocity, say thirty revolutions per minute, the balls E E will diverge from

the spindle till their centrifugal force balances their weight. Let this be the position represented in the figure. If the spindle be made to make more revolutions than 30, then the balls will diverge more than what is represented in the figure. The points *f f* will diverge, and by means of the bars *f h* pull down the one end F of the lever F H, and raise the other end H. This, by the mechanism represented in the figure, would obviously tend to shut the valve, and to cut off the supply of steam. If, on the other hand, the spindle be made to perform fewer revolutions per minute than 30, the balls will collapse more than what is represented in the figure. The points *f f* will approach to one another, and by means of the arms *f h* force up one end F of the lever, and depress the other end H. This will obviously tend to open the valve, and to increase the supply of steam. After this action is understood, suppose that by some mechanism the upright spindle is so connected with some moving part of the machinery, that when the velocity of the engine is unduly accelerated, the spindle performs more than 30 revolutions, and

1470.



that when the velocity of the engine is unduly retarded, the spindle performs less than 30 revolutions per minute, then this expedient becomes a regulator of all the inequalities of velocity arising from the variations in the amount of resistance to be overcome. The upright spindle may be connected with the fly-wheel shaft by means of an endless cord passing over a small grooved wheel *d* on the axis of the spindle, and working into a similar groove on the fly-wheel shaft, or by geering, which is a preferable mode in large engines. By properly proportioning the diameters of these wheels, the spindle may be made to perform any number of revolutions per minute. It is obvious, that by these means the speed of the grooved wheel *d* may be considered as representing the speed of the fly-wheel, and of the machinery which the fly-wheel drives. After these observations, and the remarks upon the subject we have already made, the principle which renders the governor so admirable a regulator of the velocity of the machine will be easily apprehended. Let t denote the time in seconds of a periodic revolution of the balls, and h the height in inches of e above the horizontal plane passing through the centre of the balls; then, according to the well-known formula—

$$t = \cdot 31986\sqrt{h}.$$

Let n denote the number of revolutions per minute, then we have the proportion—

$$\cdot 31986\sqrt{h} : 60 :: 1 : n = \frac{60}{\cdot 31986\sqrt{h}},$$

or $n = 187 \cdot 58 \div \sqrt{h}$, which also may be written $h = 35186 \div n^2$. We have supposed Fig. 1470 to represent the divergence of the balls when the spindle was making 30 revolutions per minute. In that case $n = 30$, and $h = 35186 \div 30^2 = 35186 \div 900 = 39 \cdot 09$ inches, or about $39\frac{1}{10}$ inches. Now suppose that the velocity of the engine was accelerated so much that the spindle performed 31 revolutions per minute; then, taking $n = 31$, we obtain $h = 35186 \div 31^2 = 35186 \div 961 = 36 \cdot 61$ inches, or somewhat more than $36\frac{1}{2}$ inches. Thus, before the spindle can perform one more revolution per minute, the plane of revolution of the balls rises $39\frac{1}{10} - 36\frac{6}{10} = 2\frac{5}{10} = 2\frac{1}{2}$ inches, which obviously would cause a very great change in the angle of divergence of the arms E *e f*. Suppose, on the other hand, that the velocity of the engine were retarded so much that the spindle performed only 29 revolutions per minute. Then, by taking $n = 29$, we find $h = 35186 \div 29^2 = 35186 \div 841 = 41 \cdot 84$ inches, or between $41\frac{3}{4}$ and 42 inches. Thus, before the spindle can perform one less revolution per minute, the plane of revolution of the balls must fall $41 \cdot 84 - 39 \cdot 1 = 2 \cdot 74 = 2\frac{3}{4}$ inches nearly, which would obviously cause the angle of divergence of the arms E *e* to diminish very considerably. The efficiency of the governor in regulating the supply of steam depends very much upon the mechanism employed to communicate its agency to the throttle-valve. We may suppose the relations of the different bars E *e f*, *f h*, F G H, and H *w*, to be such, that when the horizontal plane passing through the centre of the two balls E E is only 36·61 inches below the point of suspension *e*, the throttle-valve would entirely close up the steam-pipe, and that when the horizontal plane passing through the centres of the two balls E E is 41·84 inches below the point of suspension *e*, the throttle-valve would be fully open. On this supposition the effect of the governor would be, that the engine could never be so much retarded as that the upright spindle performed less than 29 revolutions per minute, or so much accelerated that the upright spindle performed more than 31 revolutions per minute. This would ensure that the greatest change of velocity of any

part of the machinery could never exceed $\frac{2}{30} = \frac{1}{15}$ of its mean velocity,—a variation which in practice is scarcely perceptible; so that such a governor might be considered as practically perfect. In the best modern engines the amount of variation is seldom less than one-tenth of the mean velocity. But we may easily suppose the governor to be so connected with the engine as to act with even greater efficiency than the one which we have described. The governor can be so proportioned, and so connected with the engine, as to make 60 revolutions per minute; and the mechanism connecting it with the throttle-valve may be so contrived, that when it makes 59 revolutions per minute the valve may be fully open, and that when it makes 61 revolutions per minute the valve may be entirely closed. In this case the greatest variation of the velocity of any part could never exceed one-thirtieth of the mean velocity of that part. Indeed, in theory there is no limitation to the degree of regularity which may be produced by the application of the governor. Practical considerations, however, limit the application of the principle in several ways. It has been found inconvenient, for example, to allow minute alterations of the governor to affect sensibly the position of the valve, and in order to prevent the inconvenience arising from a continual changing in its position it is found expedient to construct the governor such that even a considerable change in the divergence of the balls shall not produce too much alteration in the opening of the valve. This consideration, and several others, limit the application of the governing principle, and prevent engineers from approximating so closely to theoretical perfection, as the principle permits.

In the construction of a governor to regulate a particular engine, it is necessary to consider the position of the balls corresponding to the mean velocity of the engine, the range of motion which must be given to the arms so as to enable them to confine the variations of velocity within certain limits, and the weight of each of the balls. We proceed to consider each of these points separately.

Position of balls when moving with mean velocity.—To determine this position, we have only to consider the vertical height of the point of suspension above the horizontal plane passing through the centre of the balls when the spindle is making the average number of revolutions per minute. This is found from the formula, $h = \dfrac{35186}{n^2}$.

From which we have the following rule:—

Rule.—To determine the height of the point of suspension above the plane of the balls, when moving with mean velocity.—Divide the number 35186 by the square of the mean number of revolutions per minute. The quotient is the height of the point of suspension above the plane of the balls when moving with mean velocity.

Example 1.—In a particular engine the governor is so connected with the fly-wheel shaft, that when the engine is moving with average velocity the upright spindle makes 40 revolutions per minute. Required the proper height of the point of suspension above the plane of the balls.

In this example, $h = \dfrac{35186}{40^2} = \dfrac{35186}{1600} = \dfrac{351 \cdot 86}{16} = 21 \cdot 99$ inches; so that the proper height is about 22 inches.

Example 2.—The governor spindle is driven by the fly-wheel shaft by means of an endless cord passing over a groove on the spindle, and another groove on the fly-wheel shaft. The diameter of the groove on the governor spindle is 9 inches, and the diameter of the groove on the fly-wheel shaft is 12 inches. The engine has a stroke of 8 feet, and the mean velocity of the piston is 256 feet per minute. Required the proper height of the point of suspension above the plane of the balls.

In this example, since the mean velocity of the piston is 256 feet per minute, and the length of the stroke 8 feet, it follows that the engine makes $256 \div 8 = 32$ single strokes, or 16 double strokes per minute. The fly-wheel makes one revolution for each double stroke of the piston, and therefore the fly-wheel also makes 16 revolutions per minute. The number of revolutions of the fly-wheel shaft is to the number of the revolutions of the governor spindle inversely as the diameters of the grooves; so that we have the proportion $9 : 12 :: 16 : n = \dfrac{16 \times 12}{9} = 21\frac{1}{3}$.

Hence, according to the rule, $h = \dfrac{35186}{(21\frac{1}{3})^2} = \dfrac{35186}{455\frac{1}{9}} = 77 \cdot 31$ inches. This proportion is one never employed in practice on account of the inconvenience of the dimensions; but it is that proper to the data assumed.

The range of motion of the arms.—This depends entirely upon the amount of variation of velocity which may be permitted without detriment to the work upon which the engine is applied. We have already shown, that when the governor performed on an average 30 revolutions per minute, a variation of velocity equal to one-fifteenth of the mean velocity required only a range corresponding to a vertical height of $5 \cdot 23$ $(= 41 \cdot 84 - 36 \cdot 61)$ inches. But we shall now conduct the inquiry in general terms. Let

$v =$ mean velocity of any moving part of the machinery.
$n =$ number of revolutions of the governor spindle corresponding to v.
$h =$ height of point of suspension above the plane of balls corresponding to v.
$v + \frac{1}{2} m v = (1 + \frac{1}{2} m) v =$ maximum velocity of any moving part of the machinery
$h' =$ value of h corresponding to $(1 + \frac{1}{2} m) v$.
$v - \frac{1}{2} m v = (1 - \frac{1}{2} m) v =$ minimum velocity of any moving part of the machinery.
$h_1 =$ value of h corresponding to velocity $(1 - \frac{1}{2} m) v$.

Then we wish to find the value of $h_1 - h^1$. It is obvious that the value of n corresponding to the maximum velocity will be $(1 + \frac{1}{2} m)\, n$, and the value of n corresponding to the minimum velocity will be $(1 - \frac{1}{2} m)\, n$. Hence, according to the rule, $h^1 = \frac{35186}{(1 + \frac{1}{2} m)^2 n^2}$ $h_1 = \frac{35186}{(1 - \frac{1}{2} m)^2 n^2}$; and therefore,

$$h_1 - h^1 = \frac{32\, m}{(4 - m^2)^2} \times h.$$

This formula is too complicated to be easily expressed in the form of a rule; but its applications may easily be apprehended from the following example:

Example.—The governor of a steam-engine performs 30 revolutions per minute when the engine is moving at the average speed. Required the range as expressed in vertical height of the arms of the governor, such that the difference between the maximum and minimum velocity of any moving part should never exceed one-fifteenth of the average velocity of that part.

In this example $m = \frac{1}{15}$, and as we have shown previously, $h = 39{\cdot}09$.

$$\text{Hence, } h_1 - h^1 = \frac{32 \times \frac{1}{15}}{[4 - (\frac{1}{15})^2]^2} \times 39{\cdot}09 \text{ inches} = 5{\cdot}23 \text{ inches.}$$

We may conclude these investigations respecting the governor with a summary of the most important points in the rationale of its operation. The governor may either be considered as a conical pendulum compounded of the movements of two pendulums vibrating at right angles with one another, or it may be viewed simply as a system of revolving balls, of which gravity is the centripetal force. In the former case the governor will make half the number of revolutions that a pendulum of the same vertical height makes of vibrations; and if the speed of the governor be urged beyond this point, the arms will fly out and diminish the vertical height, until it just becomes equal to the length of a pendulum that makes twice the number of vibrations in the minute that the governor makes of revolutions. Every one knows that if the length of a pendulum be diminished, it will make a greater number of vibrations in a given time than before; the cause of which simply is, that the steepness of the arc in which the ball of the pendulum descends is then increased, and it consequently descends with a greater velocity. The length of the seconds' pendulum at the level of the sea in London is 39·1393 inches, and the number of vibrations made in a given time by pendulums of different lengths varies inversely as the square roots of their lengths. The proper speed for a governor, therefore, with a vertical height of about 39 inches, is 30 revolutions per minute, which accords with the preceding determinations; and similarly if the vertical height of governor proper to any other number of revolutions be required, it is only necessary to find the length of a pendulum, which will give twice the number of vibrations. If the number of revolutions and the length of the arm be fixed, and it is wanted to know what is the diameter of the circle described by the centre of the ball, it is necessary to find the vertical height by the foregoing rule; or the following may be adopted. Divide the constant number 187·68 by the number of revolutions per minute, and the square of the quotient will be the vertical height in inches of the centre of suspension above the plane of the ball's revolution. Deduct the square of the vertical height in inches from the square of the length of the arm in inches, and twice the square root of the remainder is the diameter of the circle in which the centres of the balls revolve. The vertical height of the governor is in every case taken as the distance between this circle and the point of suspension.

In considering the governor as a system of bodies acted upon by centrifugal and centripetal forces, the same results are obtained as where it is regarded as a conical pendulum. The horizontal distance of the ball from the spindle, divided by the vertical height, will give the amount of centripetal force; and the velocity of revolution requisite to produce an equivalent centrifugal force may be found by multiplying the centripetal force of the ball in terms of its own weight by 70·440, and dividing the product by twice the distance of the centre ball from the centre of the spindle in inches. The square root of the quotient is the right number of revolutions of the spindle per minute. Considering the question in this way, we first fix the length of the arms and the diameter of the base of the cone, or what is the same thing, the angle at which it is desired the arms may revolve; and then, by the rule given above, we make the speed of revolution such that the centrifugal force will keep the balls in the desired position. Many persons find some difficulty in considering the governor as a pendulum, inasmuch as it may be driven at *any speed;* but each particular speed has a vertical height of the centre of suspension above the plane of revolution *proper to itself*, and one condition cannot be altered without affecting the other. The method of considering the governor, however, as a revolving system of balls, does not involve this difficulty, and to many engineers it will therefore be the most satisfactory.

Weight of balls.—The proper weight of balls depends principally upon the nature of the mechanism employed to transmit the agency of the governor to the throttle-valve. In practice they are generally somewhere between 30 and 80 pounds each. It may be remarked in general, that of two governors performing the same number of revolutions per minute, the one which is farthest removed from its throttle-valve, and which is consequently connected with it by the most complicated mechanism, ought to have the heaviest balls. No general rule founded upon theory can be given for determining the proper weight of these balls in any particular case. In fact, according to theory, the agency of the governor is altogether independent of the weight of the balls; for the balls perform the same number of revolutions per minute, and revolve at the same distance from the spindle, whatever is their weight. The truth of this remark will appear clear enough if each ball be supposed to be compounded of a number of smaller balls, each of which would certainly keep the same position as the larger ball; and every particle may therefore be supposed to act for itself. Though the centripetal force of the balls be increased, therefore, by adding to their weight, yet, inasmuch as their centrifugal force when in motion is increased in the same proportion, their position, when the governor is set into revolution, cannot be

affected thereby. An increase in the weight of the balls gives the governor more power to open or close the throttle-valve, but does not in any other way affect its operation. Large engines, where the valves are large and stiff, require to have the balls of the governor of corresponding size, especially if the connections between the governor and throttle-valve are stiff and complicated; but in no other respect is the size of the balls of importance.

The principle on which the governor acts, necessarily supposes temporary variations of the speed The governor, theoretically speaking, does not maintain a uniform velocity, but restores it after it has been disturbed. Suppose that, either by reason of the diminished load upon the engine, or an increased evaporative power in the boiler, the speed of the engine is accelerated, the governor, being immediately affected, will cause a corresponding alteration in the throttle-valve; but in general, this alteration being too much, the velocity of the engine will be too much retarded. This second error will again affect the governor in the contrary way, and the speed will now be increased beyond the proper limit. Thus a succession of alternations of effect will ensue, until the governor settles down into the position corresponding to the proper speed. The agency of the governor is never brought into use before a change of velocity has taken place. The very supposition that a governor acts, presupposes that a change of the speed has ensued; and which, though it corrects, it cannot prevent from arising.

Varieties of governors.—The conical pendulum is the governor employed almost universally for the regulation of the speed of rotative steam-engines. Yet other kinds have been introduced, and in some instances with a good effect. One very sensitive governor consists of a cylindrical double bellows, worked by the engine, and furnished with a small cock at the orifice at which the air escapes, so that it may be contracted at pleasure. When the engine runs beyond the right speed, an additional quantity of air is taken in by the bellows, which, as it cannot obtain a free exit by the orifice contracted by the cock, raises up the superior or floating part of the bellows, to which a rod is attached that closes the throttle-valve. When the speed slackens, the floating part of the bellows subsides, and opens the throttle-valve, until, after a few fluctuations, a mean point is reached—determined by the size of the orifice left for the issuing air—at which the floating part of the bellows will remain nearly stationary. A bellows on this plan has been for some years attached to the engine that gives motion to the machinery in Truman and Hanbury's brewery, and its operation is spoken of in the highest terms.

Another plan of governor was some years ago contrived by Mr. Hick, of Bolton. Upon an upright spindle he wound a spiral feather, and then fitted upon the spindle a single ball, so that the ball might be moved up or down on the spindle, but would turn on its axis in the operation. To the ball were fixed two vanes, which, impinging upon the air when the ball was put into revolution with a high velocity, caused the ball to mount up on the spiral feather or thread. So long as the speed of the shaft upon which the ball was placed remained moderate, the ball continued at the foot of the spiral; but when the speed was increased, the impact of the vanes upon the air so far resisted the rotation, that the ball rose on the spiral feather in opposition to the force of gravity; and in its ascent it closed the valve. A governor upon this plan seems to be well adapted for steam vessels, if a spring be substituted for the ball. The ordinary governor, however, may be rendered applicable to the marine engine if the balls be made to move out horizontally instead of in an arc of a circle. It is clear that a common governor would not act at sea without this modification, as the balls would diverge or collapse at every heave of the ship. In Siemen's chronometric governor a clock movement furnished with a weight and pendulum is employed. The clock movement carries round a bevel-wheel at a uniform speed; and another bevel-wheel of the same size, and situated upon the same axis, is carried round by the engine in an opposite direction. A bevel-pinion at the end of a crank-arm geers with both wheels in the manner of a differential motion, and to this crank is attached a rod communicating with the throttle-valve. When both wheels are moving at the same speed the pinion remains stationary, but if one wheel travels faster than the other, the crank will be carried round upon its axis, and will thereby affect the throttle-valve. There appears to be too much complication in this contrivance to enable it to gain an introduction into practice, unless a clock movement be required for other uses than that of the engine.

The governor, as at present applied to regulate the steam-engine, acts only on the throttle-valve, to restrain the flow of steam into the cylinder; but in our humble judgment it ought also to act upon the injection-valve, to restrain the flow of water into the condenser. In all cases of large fluctuations of velocity, inconvenience and danger is the inevitable effect of the injection water being left without due regulation, and in steam vessels in particular, accidents are frequently traceable to this cause. If the injection-cock be adjusted to give admission to the right quantity of water when the engine is working with a mean velocity, it will clearly admit too much when the velocity is arrested so as to be brought to one-half or one-fourth of the common speed; and as the air-pump cannot, when it is working so slow, deliver the water which rushes into the condenser in undiminished quantity, the engine becomes choked with water, and the water sometimes runs back into the cylinder, and occasions fracture by resisting the descent of the piston. The most common cause of breakages in steam machinery is the entrance of water into the cylinder. Sometimes it passes over with the steam, when priming in the boiler takes place; and at other times it finds its way from the condenser, and this will more frequently happen if the cylinder exhausts from below than if it exhausts from the top or superior portion of the valve casing. The right remedy for this danger is to apportion the quantity of water admitted to an engine to the quantity of steam; and this may be accomplished by placing a throttle-valve in the injection-pipe, which will also be operated on by the governor; but little condensing water will then be admitted when there is but little steam to be condensed, and the engine will neither be burdened by needless water nor starved into inefficiency by an inadequate supply.

The cataract.—The governors we have already mentioned are chiefly applicable to the rotative engine. The accredited governor of the single-acting or pumping engine, is the cataract, of which instrument there are many varieties. The cataract consists of a small pump plunger, and barrel, set in a cistern of water, the barrel being furnished on the one side with a valve, opening inwards, through which the water obtains admission to the pump chamber from the cistern; and on the other by a cock,

through which, if the plunger be forced down, the water may be sent out again, with a rapidity proportionate to the size of the orifice left by the cock. The engine, in its upward stroke, which is accomplished by the preponderance of weight at the pump end of the beam, raises up the plunger of the cataract by means of a small rod, represented in the drawing of valve geering already referred to—the water entering the pump chamber through the spindle valve, which is also represented, and filling the pump chamber completely. By the time the engine reaches the top of the stroke, it liberates the rod by which the plunger has been drawn up, and the plunger then descends by gravity, forcing out the water in the barrel, and at the same time opening the injection valve. If the cock of the cataract be shut, it is clear that the plunger cannot descend at all; and as, in that case, the injection valve cannot be opened, the engine stands still: but if the cock be slightly opened, the plunger will descend slowly, the injection valve will slowly open, and the engine will make a gradual stroke as it gains the water necessary for condensation. The degree to which the cock is opened, therefore, determines the speed at which the engine moves; so that by the use of the cataract, the speed of the engine may easily be adjusted to the quantity of water in the mine. There are other varieties of cataract employed besides that here described, but they all depend upon the same general principle. In some cases air is used instead of water, and in others a cylinder of oil is employed, fitted with a piston with a valve after the manner of a pump bucket, and a small side pipe, fitted with a cock, which communicates between the spaces on each side of the piston. When the piston of this cataract is forced down, the oil easily ascends through the valve into the superior part of the cylinder; but when it is drawn up, the oil can only escape by the curved pipe, from the space above the piston to the space beneath it, by passing through the contracted orifice of the cock; and, though a considerable counterbalance be applied, the piston, if the cock be partially closed, can ascend but slowly. The effect is the same as in the arrangement first described.

Expedients for ascertaining the state and power of an engine.—Water gages.—There are three kinds of water gages: the first the ordinary gage cock, the second the glass gage, and the third the float. The gage cock, on being turned, shows whether it is water or steam that exists at the level at which it is inserted. There are usually three gage cocks inserted in each boiler, at different levels; and the rule is, to so feed the boiler that there will be steam in the top gage-cock, and water in the other two. The glass gage consists of a glass tube set in front of the boiler, communicating in its superior portion with the steam space, and in its inferior portion with the water within the boiler, the position of the tube being so adjusted that the water level stands at about the middle of its length. The tube is connected at the top and bottom to the boiler by means of sockets furnished with cocks, so that the tube may be blown through by the steam to clear it, and the water and steam may be shut off if the glass breaks. It is unsafe to trust to the glass gages altogether as a means of ascertaining the water level, as sometimes they become choked, and the water continues to stand high in the tube though it may have sunk low in the boiler. If the boiler be short of steam, however, and a partial vacuum be produced, the glass gages become of essential service, as the gage cocks will not operate in such a case, for though opened neither steam nor water will come out, but air will rush in. This sometimes occurs in practice, and glass gages are then found to be of especial value. We may mention, however, that a vacuum in the boiler should never be suffered to occur, as if the boiler is short of steam the throttle-valve should be closed to a corresponding degree, or a higher degree of expansion should be employed, so that the due pressure of the steam may be maintained. A better economy is to be realized by this plan of procedure than by suffering the engine to draw from the boiler the attenuated steam. In steam vessels the operation of blowing off cannot be performed, unless the pressure of the steam be considerably above that of the atmosphere, and the neglect of this operation entails evils which are of serious moment, and which are very expensive to cure.

The float gage consists of a float resting on the surface of the water, and communicating with an index, so that the fluctuations in the water level are, by reference to this index, made apparent. The float is usually of stone or cast-iron, but is so balanced by a counter weight as to make its operation the same as if it were a buoy of timber. In land boilers a float is generally employed to regulate the admission of the feed-water, and the same float may also indicate the height of the water within the boiler. The feed-water is admitted from a small open cistern at the top of the stand-pipe, as shown in Fig. 1471. At the bottom of the cistern is a valve, which the float opens or closes, and into the cistern the water is poured by the feed-pump. When the valve is open the water runs down into the boiler, but when closed it runs away by an overflow shoot. The foot of the stand-pipe penetrates to near the bottom of the boiler, so that steam cannot escape by it, but the water rises in the stand-pipe to a height proportionate to the pressure of the steam, and a most effectual safety-valve is thus provided, which will come into operation in the event of a dangerous pressure being attained. In the stand-pipe a float is placed, which rises and falls as the pressure of the steam varies, and opens or closes the damper leading from the boiler flue to the chimney. Some stand-pipes are contracted in their diameter below the level at which the damper float usually operates, and danger has arisen from this cause; for the float has descended into this narrow neck when there was no longer a pressure of steam in the boiler, and by stopping up the passage it has prevented the access of the feed-water The length of the damper chain should be so regulated as to obviate accidents of this description, which are not unlikely to burst the boiler, by causing the boiler bottom or flues to become red-hot.

1471.

Salt gages.—In steam vessels it is a commendable practice to apply salt gages to the boiler, so that the water may never be suffered to reach an injurious degree of saturation. These gages usually consist of glass balls, which operate on the principle of the hydrometer, rising to the surface when the water becomes highly concentrated, and therefore heavier. In some instances bulbs of this description, enclosed in a large glass tube, are fitted to the front of each boiler; but the general plan is to draw off some of the water into a separate

vessel, and then to test its saltness by an instrument provided for the purpose. The Don Juan steamer was fitted with large copper balls, to determine the saltness of the water in the boiler: they were of course totally immersed in the water, and as the water increased in density they rose and opened the blow-off valve, which was made of such a construction as to be capable of being easily opened. There is too much refinement probably in this expedient, and the ball requires to be large to realize a sufficient motive force to make the action of the instrument certain, yet the operation of the plan is very complete, especially if conjoined with a self-acting feed, as was the case in the instance referred to. A good salt gage is still a desideratum, for the plan of drawing off water from the boiler, and testing it by an hydrometer, is very inconvenient in practice. A salt gage, to be a convenient instrument, should indicate, by a hand or other simple appendage, the density at the time of observation of the water in the boiler, and such an instrument becomes of especial importance if the amount of water blown off be regulated by the position of the feed-cocks, as is done in the case of Mr. Lamb's blow-off apparatus for steam vessels, which is now gaining an extensive introduction. In this apparatus the mouth of the blow-off pipe within the boiler is situated near the water level, whereby it catches and removes from the boiler the particles of impalpable matter which, by their subsidence on the flues, occasion scale.

Mr. Lamb attaches a valve to the mouth of the blow-off pipe regulated by a float, with the view of preventing the steam from blowing off when the water has subsided below the said mouth, which is situated about 12 inches beneath the average water line. The float is made of copper, of the form of an oblate spheroid, with a tube passing through it for the reception of a spindle, the position of which in reference to the float is regulated by nuts above and below the float, which connect with screw threads cut upon the spindle. The valve resembles a flute key. The lower end of the spindle is attached to the valve arm, so as to enable the float to exert a greater power, and the upper end of the spindle moves in a guide attached to any convenient part of the boiler. By this apparatus the operation of blowing off is continuously performed; but when the salt gage shows that the quantity of water blown off is either needlessly great or insufficient, the position of the feed-cock is altered so as to give a diminished or increased supply. When more feed-water is admitted, the float upon the surface of the water opens the blow-off valve more widely, and permits a larger quantity of water to be blown out; and when less feed-water is admitted, the contrary effect is produced. The operation of the float, therefore, is to maintain the water at a uniform level, and also to preserve the water within the boiler at a uniform density so soon as the right position of the feed-cock is ascertained. In boilers which are thus worked, or to which brine pumps, or any continuous blow-off contrivances are applied, an efficient salt gage is indispensable, as there can otherwise be no intimation of the accidental interruption of the operation, and much mischief may be the result. In the ordinary way of blowing off, where the engineer keeps the blow-off cocks open until the water level has descended any given number of inches, it is certain that if the water level descends, a certain volume of super-salted water has been ejected; unless, indeed, as has sometimes happened where there is a difference of pressure in the different boilers, one boiler has discharged its contents into the other when all the blow-off cocks are opened at once. But in the ordinary operation of blowing off one boiler at a time, a determinable quantity of water is expelled by blowing out at determinate intervals with a certainty which leaves nothing to the chances of accidental derangement, and which the use of the salt gage in the case of boilers fitted with any description of continuous blow-off is indispensable to insure.

Steam gage.—The steam gage consists generally of a simple tube, sometimes of glass and sometimes of iron, bent so as to form the letter U. One of the ends is placed in communication with the boiler, and the other end is open to the atmosphere. Into the bent part of the tube mercury is poured, which, if not acted on by the steam, will stand at equal heights in both legs of the tube. If, however, the steam be admitted to act upon the mercury at one of the extremities of the tube, it will force it up in the other leg, and may be made to indicate the amount of pressure on a divided scale. The scale is commonly divided into inches and parts of an inch, each inch corresponding to a pressure of very nearly one pound on the square inch. Some people prefer estimating the elasticity of the steam by pounds per circular inch. For this purpose each of the divisions of the scale ought to be $1\frac{3}{10}$ inches, and these divided again into 10 equal parts, when the pressure in lbs. and tenths of a lb. will be shown by the scale. When the tube is constructed of iron, it is necessary that a float of wood resting on the top of the mercury should ascend above the tube, and indicate on a proper scale the place of the mercury. It is clear that every inch the mercury rises in the open end of the tube occasions a difference of level of two inches, for the level in the leg pressed on by the steam falls an inch at the same time that the level in the open end rises an inch. Some steam gages consist of a straight glass tube, with one end terminating in a small cistern of mercury, while the other end is open, and the mercury is forced up into the tube by the pressure of the steam. In this case the graduation has to be such that a pound pressure will be represented by two inches in height upon the scale, for the level of mercury in the cistern does not subside appreciably by the rise of mercury in the tube. The siphon gage is the one generally employed, and it appears to be entitled to the preference it enjoys. Every boiler ought to be provided with a steam gage as a precaution of safety, as well as a means of seeing that the steam is kept steadily up. If the pressure rises to any dangerous pitch, the mercury will be blown out of the gage, and the escape of steam will notify the existence of danger. In such case, if the safety-valve cannot be raised, from derangement or otherwise, the best plan is to open the blow-through valve of the engine. To start the engine might cause a flow of water from the feed-pump over hot plates within the boiler, if the water be at the same time low within it, and an explosion might be the consequence of such an indiscretion.

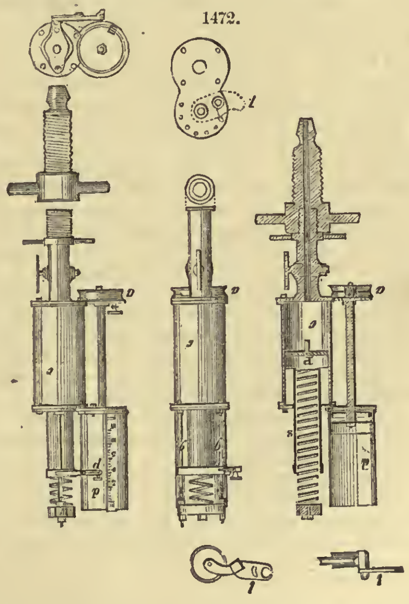
Vacuum gage.—The vacuum gage is a barometer for determining the relative elasticities of the air and of the attenuated vapor in the condenser. It consists of a glass tube, of which the inferior orifice is inserted in a small cistern of mercury, while the superior orifice is fitted with a small pipe, which communicates with the interior of the condenser. The air presses on the surface of the mercury in the cistern, while the pressure of the condenser vapor only exists within the tube, and the mercury rises in the tube to a height corresponding to the difference of these pressures—usually to a height of about 27

inches. There is a good deal of oscillation in the mercury of a vacuum gage if the cock in the pipe leading from the top of the tube to the condenser be opened fully, and it should therefore be nearly closed before the observation of the quality of the vacuum is made, else it will be very difficult to tell at what point the mercury stands on the average, in consequence of its rapid rising and subsidence. In the graduation of vacuum gages reference enough is not generally had to the size of the mercury cistern, which is usually made small; and as the subsidence of the level of the mercury in the cistern falls considerably when the tube becomes full, the graduation, if made in inches, is correspondingly inaccurate, as the divisions should be less than an inch apart to represent inches, if the surface of the mercury in the cistern falls. Some vacuum gages are made on the principle of indicating the difference between the vacuum in the condenser and a perfect vacuum, instead of the difference between the vacuum in the condenser and the pressure of the atmosphere. This species of vacuum gage is much used in sugar refining, and is convenient there from its portable nature; but it has not met with any extended adoption for the uses of the steam-engine. A siphon vacuum gage, like the steam gage in form, is also sometimes used; but the straight glass tube, arranged in the manner we have described, is generally preferred to any other arrangement.

The indicator.—The indicator is an instrument for determining the amount of power actually exerted by an engine. In computing the power of engines, one important element is the unbalanced pressure of the steam on the piston; and any inaccuracy in the statement of this particular must vitiate the calculation, and give an erroneous result. In all ordinary cases, even when no expansion geer is used, it is wrong to reckon the pressure of the steam in the cylinder as uniform, or the condensed vapor as of a constant elasticity; and to assume that the pressure in the cylinder is the same as that indicated by the steam gage, is to introduce a fallacy into the computation of power. The use of the indicator is to measure and register the variations of pressure during a complete stroke of the engine, and thus to obtain accurate data whereby the effective power of the engine may be computed.

The indicator consists of a small cylinder *c*, Fig. 1472, placed in connection with the cylinder of the engine either above or below the piston, and fitted with a piston P, which is connected with the spiral spring *s*. By opening the cock of the indicator the steam is admitted below the piston P, on which it presses during the whole stroke. If the pressure were uniform, the piston would remain stationary; but if the pressure vary, the piston will have corresponding movements either up or down. If a pencil *p*, be attached to the piston-rod, it will register the variations of pressure upon a piece of paper held against it; but, unless some provision were made to give a clear space upon the paper at each instant of time, one mark of the pencil would be upon the other, and the registration could not be deciphered: but, if the paper receives a continuous lateral motion in one direction during the down stroke of the

1472.



piston, and a reversed motion during the return stroke, while the pencil moves vertically, a continuous line will be traced upon the paper, which will inclose a space, and the vertical ordinates of the figure will represent the effective pressure during a complete stroke. Instead, however, of using a plain surface, as was done in Boulton and Watt's establishment for some time after its formation, it is now the universal practice to wind the paper round a cylinder, or roller, which is made to turn upon its axis with a reciprocating motion, and the apparatus is thus rendered more compact. If the pressure of the steam were uniform, the line described upon the paper would be in a plane perpendicular to the axis of the roller, so that, if the paper were unrolled, the line would be straight. The paper is fastened to the roller by means of a catch *h*, the edge of which is graduated. Before the instrument is connected with the steam cylinder, the roller is set in motion, and the pencil then describes a neutral line, which repre-

sents the pressure of the atmosphere—any vertical ordinate above this being the steam pressure above that point, and any vertical ordinate below, the pressure below it. If the connection between the indicator and the cylinder be now formed, while steam is entering the cylinder, the piston of the indicator will rise; and, if steam is escaping from the cylinder, it will fall; the extent of rise and fall being regulated by the spiral spring, which yields more as the pressure becomes greater. The vertical motion of the pencil, combined with the circular motion of the roller, will form a curve more or less regular, the vertical ordinates of which represent the values of the steam pressure and vacuum during a complete stroke, measured by the scale which is marked upon the roller clasp. The graduation of this scale depends upon the strength of the spring *s*, which forces the piston down when the steam ceases to force it up; because, the stronger the spring is made, the smaller is the distance through which steam of a given force will compress it by raising the piston. The alternate motion of the roller is given by connecting it with any reciprocating part of the engine, such as the parallel motion, by means of a cord attached to the pulley *a*, which is fixed upon the same axis as the paper roller *d*. This cord gives motion in one direction, and the return motion is received from a spring *m*, which is coiled up like a watch-spring; *l* is a guide pulley for changing the direction of the cord when it passes from the pulley *a*; it is not shown in its place except in the bottom plan, where part of it is dotted in.

Let us now suppose the engine to be in motion, and the stop-cock of the indicator closed. If the cord be drawn out by hand, or connected with the engine, the pencil pressing against the paper will describe the horizontal line representing the atmospheric pressure; and if, when the piston is at the top of its stroke, the indicator stop-cock be opened, it will commence its registration. When the steam begins to rush into the cylinder, it will, of course, also press upon the piston of the indicator, which it will raise, and with it the pencil; and the roller, with the paper upon it, being moved by its connection with the engine, a line will be traced upon the paper, which rises higher up on the cylinder as the pressure of the steam increases, and comes lower upon it as the steam pressure subsides. The area of the curve traced out by the pencil, therefore, represents the pressure on the piston through all its variations, and, when multiplied by the number of strokes, represents the power exerted by the engine. This power has no connection with the *nominal* horse power, which is determined by the dimensions of the engine, and which does not vary with variations in the pressure of the steam; but it is the *effective* power, or the power actually exerted.

The indicator, however, not merely tells the amount of power exerted by every stroke of an engine, but the nature of the faults by which the power is impaired. A particular form of the indicator diagram shows that the ports of the cylinder are too small; and the indication in such a case obviously is to enlarge them. If the valve be wrongly set, the indicator will explain the nature of the imperfection, and its adjustment then becomes easy. By the indicator too the amount of power consumed by each of the several mechanisms of a factory may be determined, and the relative values of different oils fixed that may be employed for the lubrication of the shafts. If, for example, it is wanted to know the amount of power consumed by a fan or a saw-mill that may be driven by the engine, the machine in question has only to be put in connection with the engine, while all the rest of the machinery of the factory is cast off; and if the indicator be applied to the engine, the amount of power consumed in driving the one machine will be determined; and then it will be found, by taking another diagram, with all the machinery on, what proportion this part bears to the total power. In testing the quality of oils, if it be found that the engine requires more power to drive the shafting with one kind of oil than with another, that which involves the largest expenditure of power is, of course, the worse. To read off the indications of the indicator is a thing every one may do after the foregoing explanation. The pencil describes a curved line inclosing a space. Across that space any number of lines may be drawn at right angles to the atmospheric line. The lengths of the lines are then measured on a scale, and their mean taken, which mean represents the power exerted. The indicator is an invention of Watt's, but it does not very clearly appear who it was that first applied the pencil to trace a curve. The application was, however, first made at Soho, probably by Mr. Southern or Mr. Creighton.

Continuous indicator.—A continuous indicator is an instrument that will not merely ascertain, but also register the work done by an engine during any given period, whereby the performance of one engine may be compared with the performance of another, to the end of ascertaining which is the most economical in fuel. In Cornwall this object is accomplished by means of a counter, which merely registers the number of strokes made by the engine; but this expedient will only answer where the load upon the engine is constant and easily measurable, and becomes of but little avail in a steam vessel, where the load is continually varying. The invention of an instrument of a simple kind, that will record the varying power of the engine under all circumstances of speed and variation of expansion, becomes an object of no trivial importance, when it is recollected that such an instrument is indispensable to the success of any effectual scheme of registration. This chasm has now been filled up by W. H. Linslay. By registration we mean the determination by an authorized person of the power exerted by steam vessels, or, in other words, the *work done* in relation to the *fuel consumed*, and the publication of these results obtained from a large number of steam vessels at regular intervals; so that it may appear on the face of a table suitably drawn up what steam vessels are the most effectual. These published tables would, therefore, be identical in all their main features with the tables published in Cornwall by the Messrs. Lean; and indeed the measure we propose consists in the extension to steam vessels of the system of registering the *duty* of engines pursued in Cornwall, and which has produced such beneficial effects in that district.

The best proof of the saving in fuel derivable from the plan of registering the duty of steam-engines consists in an enumeration of the wonders it has already done; and we find that the amount of work performed in Cornwall by a bushel of coal, represented by 20,000,000 in 1815, had arisen to 60,000,000 in 1843. Nor is this a solitary case, but, on the contrary, it is the *average* duty of all the engines registered at the two periods, so that the expense of fuel to do the same amount of work is at present only one-third of what it was in 1815, and we think we may add only one-third of what it would have been

now, had the plan of registration not been adopted. The Messrs. Lean have drawn up a table which makes the value of this system very conspicuous, and from which it appears that the Cornish mine owners are now saving about £85,000 per annum in their limited operations, by the simple expedient of registering and publishing the duty of their engines. Such a practice puts all the engineers upon their mettle, and induces an emulation out of which improvement cannot but spring; and at the same time it stimulates all engine attendants to a more sedulous attention, as any negligence on their part will be sure to tell to their disadvantage. If such a saving can be realized out of the contracted sphere of Cornish engineering, what a magnificent result might not be realized by the application of the plan to the innumerable steam vessels of this country! Yet the saving in the cost of the coal in the case of steam navigation, important as it would be, is not the greatest benefit of such an economy: the powers of steam navigation would be prodigiously increased, and its profits correspondingly augmented, by any improvement by which the quantity of coal carried was materially lessened; for steam vessels could then go farther without a relay of coal, or could carry more cargo, and the growth of our steam marine would just be in proportion to the extension of the limits which now hinder its development.

It is needless, however, to dwell much on the advantages of the system of registration, as they must be conspicuous enough to every one who gives attention to the subject. Professor Moseley professes to have invented an indicator of the continuous kind, but it is far too complicated for ordinary practice; and as some of the parts drive the other parts by friction surfaces, which are apt to slip should a little oil chance to fall upon them, its indications are correspondingly uncertain. A suitable indicator being obtained, every steamer of any pretensions should be provided with one, and an inspector should then be appointed, in whose skill and honesty all parties have confidence, and whose business it should be to examine the indications of the several instruments, and make up from thence tables of the performance of each vessel, which should periodically be published. The quantity of coal consumed could of course only be got at by a reference to the coal accounts of the several vessels; and it would be a good thing if those coal accounts were all kept upon a uniform plan to facilitate the discovery of this element.

A continuous indicator of a very complete description was some years ago brought under the notice of the British Association by Dr. Lardner, though its expense and complication were too great to warrant its introduction in practice. A web of paper was wound upon a small brass drum, and a larger drum, which was put into revolution by means of clock-work, wound the web of paper off the small drum on to itself. At suitable distances round the larger drum pencils of different colors were placed, which were acted upon by floats placed in siphon tubes of mercury, to which the steam-pipe, condenser, &c., were respectively connected. When the pressure of steam in the boiler varied, the pencil attached to the float in the siphon gage communicating with the boiler was elevated or depressed correspondingly, and traced a line upon the drum above or below the right position. At the termination of the voyage the paper was taken off and translated into words, and the difference in the colors of the different pencils prevented the lines made by each from being confounded with any other. There was more trouble connected with the use of this instrument than engineers would willingly take, and more expense than the proprietors of steam vessels would willingly incur, added to which it took no satisfactory cognizance of any variation in the degrees of expansion, though that is the most important of the elements demanding registration.

Counter.—The counter is an instrument with wheelwork so contrived, that, by every stroke of the engine, an index hand is moved a certain distance forward, so that it registers or counts the number of strokes made by the engine during any given period. The construction of the counter varies very much: in most cases, however, the wheels are moved round by a pendulum attached to some vibrating part of the engine, the wheel being carried on one tooth by every vibration. Some of the French counters are extremely neat and portable, being much like a pedometer watch in size and appearance. A very elegant counter for locomotive engines has been contrived by Mr. Adie: an endless screw works into the rim of two small wheels, situated on the same axis, but one wheel having a tooth more than the other. A differential motion is thus obtained, of great slowness, for the wheel with the additional tooth will only move slightly more slowly than the other wheel, and the result is indicated by the difference of the two speeds. The end of the screw is attached to a revolving part of the engine, by means of an appropriate fastening, and the wheels hang down like a pendulum from it, and do not turn with the revolving part in question, so that the wheels are turned on their axis by the screw, without any thing of the nature of reciprocation. The counter was first introduced by Mr. Watt, and was attached by him to the Cornish engines for the purpose of showing the proportion of savings in fuel due to him from the application of his improved engine; and in the case of those engines which were uniformly loaded, the counter afforded a correct indication of the power exerted. The number of strokes of the engine multiplied by the capacity of the pump, and the height through which the water is raised, will give a quantity representative of the engine power; and in the case of pumping engines, the indications of the counter will enable us to determine the *duty*, the registration of which has in Cornwall been productive of such beneficial effects.

Dynamometer.—In screw vessels the forward thrust of the screw has been measured by a dynamometer, an instrument constructed on the principle of a weighing-machine, in which a small weight or spring pressure at the index will sustain a much greater weight or pressure at the other end. In the Rattler screw steamer the forward thrust of the screw, as determined by the dynamometer, was found to be about four tons, and it was also found that when a piece of paper was drawn slowly along beneath the index, a pencil attached to the index described upon the paper a serrated line showing great fluctuations of pressure in the different positions of the screw. The *greatest* thrust is when the screw blade is in a line with the stern post. A dynamometer has also been employed in Woolwich dockyard to test the tractive force of paddle-wheel steamers. Morin's dynamometer is usually employed for ascertaining the resistance of railway trains. It consists substantially of two blades of steel, the flexure of which indicates the resistance.

ENGINE, VARIETIES OF THE STEAM.—*Condensing and high-pressure engines.*—Steam-engines of every kind are divisible into two great classes—high-pressure engines and condensing engines. Condensing engines are sometimes also worked with a high pressure of steam, and the distinctive appellation of high-pressure engines is applied to engines of which the steam is not condensed. All locomotive engines are of the high-pressure variety; and generally all engines are made on the high-pressure plan, where the carriage of condensing water would be inconvenient, or the first cost of the machine becomes a point of more importance than an increased consumption of fuel. High-pressure engines are necessarily more expensive in fuel than low-pressure engines, as they occasion the loss of the power derivable from a vacuum; and as the quantity of heat in the *same weight* of steam is nearly the same at all pressures, there is no countervailing source of economy to compensate for this deduction. Where high-pressure steam is employed, it is expedient to make the pressure considerable, as the deduction to be made for the pressure of the atmosphere is less in proportion, with a high, than with a moderate pressure. Some locomotive engines are worked as high as 90 pounds on the square inch.

The pumping engine.—The pumping engine, as arranged by Watt at an early period of his career, and the modern pumping engine, differ from this primitive type only in a few details of secondary importance; excepting, however, the use of steam of a higher pressure, and the larger employment of the principle of expansion, by which a greatly increased economy of fuel has been realized.

All the Cornish engines are furnished with a steam-jacket to the cylinder, and, in some cases, a flue winds spirally round the jacket, carrying hot air from a small fire in the engine-house, to maintain the temperature of the steam unimpaired. Where this is not done, the cylinder is encased in a large jacket, filled with some non-conducting substance, or is covered with wood.

In most pumping engines one end of the beam is made longer than the other, the intention being to enable the cylinder to have a long stroke, without communicating such a velocity to the pump buckets as will make them strike hard, and wear themselves quickly out. One advantage of a long stroke is, that high-pressure steam may be used without being obliged to make the parts inconveniently strong; for the principal parts of the engine have to be made of the same strength whatever be the length of the stroke, and to increase the diameter of the cylinder, to compensate for shortness of the stroke, involves the necessity of a strong and expensive engine. Woolf's plan of employing two cylinders is sometimes used as an alternative remedy, and in some recent engines the plan has been much simplified, by placing the small cylinder on the top of the large one, and working both with the same piston-rod; although there is less irregularity in the impelling force, there is greater complexity in the machine, so that a long stroke with an unequal beam appears to be a preferable expedient.

The pump valves of engines working high lifts are a continual source of trouble and expense, and many expedients have been contrived to abate the shock and tremor caused by their rapid closing. Of these, the best is probably the valve known as Harvey and West's, which is, in all its material features, identical with the balance valve. This valve presses down with very little force, and an annular recess is frequently made in the pump bucket, which is filled with end-wood, on which the valve falls. In some engines canvas valves are used even for the air-pump of engines which are intended to work at a high speed—in some cases with good effect; though in others, probably from the employment of an inferior quality of canvas, the valves have worn out very quickly. The bucket consists of a metal disk, perforated with a large number of small holes, and these holes are all closed by a canvas disk, which rises and falls like a common pot-lid valve; with the exception that it is bound down at the eye, and the edges only left. India-rubber has been tried as well as canvas, but it sinks too much into the holes, and has not answered so well.

If there be any case in which the use of an engine beam can be excused, it is in the case of a pumping engine; direct action is so inconvenient and precarious over the mouth of a mine. The main beam rests on a wall of masonry near the mouth of the mine, as may be seen by a reference to the plate of a "Cornish pumping engine." At the one end of the beam is the cylinder, and at the other end the pump-rod, which penetrates into the mine. From the pump-rod end of the beam the rods for working the air-pump and feed-pump are suspended. The air-pump is shown in dotted lines, and beyond it appears the condenser, situated in the cold-water cistern, with a valve attached to the end of a curved pipe, for admitting the injection water—the valve being wrought by the cataract which stands beneath the valve geering. A rod passes through the end wall of the house, for adjusting the position of the centre of the radius-bar of the parallel motion. The cylinder end of the beam is armed with catch-pins, which strike on the spring beams stretching from the lever wall to the end of the house, if the piston proceeds down so far as to endanger the cylinder bottom. The feed-pump stands on the top of the eduction pipe: the valve geering we have already explained. It is usual in the Cornish practice to make the lowest pump of the series of lifts a lifting pump, and all the others forcing pumps. The plungers of the forcing pumps are more easily packed than the buckets of the lifting pumps, and there is not the same risk of drawing air; but the lowest pump is made a lifting one, to facilitate extensions to a lower level, and also to prevent the pump valves from becoming inaccessible if the water accumulates in the mine.

Rotative engine.—We shall not here dwell upon any description of the ordinary rotative or mill-engine, as we look upon it now as a mere piece of antiquity.

Marine engine.—The marine engine has now become the most important variety of the steam-engine, not merely on account of the great extension of steam navigation, but because it is fast superseding the ordinary steam-engine, even for land purposes. We shall therefore enter into the consideration of the structure and operation of this engine with considerable fulness of detail, and much of what we say will also be found to illustrate the merits of the other varieties of engine.

Paddle-wheels.—If a body moves through a quiescent fluid with a given velocity, or if a fluid moving with a given velocity impinge against a body at rest, the resistance will in either case be as the square of the velocity, while the power requisite to overcome that resistance will be as the cube of the velocity; so that if the velocity of a steamer be doubled, the resistance experienced in passing through the water becomes four times greater than before, and the power required to achieve that doubled speed eight

times greater than before. This is explained by the circumstance that the resistance of a body moving in a fluid is proportionate to the number of particles struck and the velocity with which they are struck: as twice the number of particles are struck, and each particle with twice the force, there is four times the resistance; and as the strain occasioned by this resistance is four times greater upon the engine, and the engine has at the same time to work at twice the speed, there must be four times the expenditure of power.

The absolute resistance which a quiescent fluid opposes to a plane surface moving through it with a given velocity, is equal to the weight of a column of the fluid whose base is the plane, and altitude the same as that which is due to the velocity of motion; that is, the height through which a heavy body must fall to acquire that velocity by the action of gravity. Reduced to a simple Rule,

$$\text{Resistance} = \text{area} \times \text{velocity squared} \times 0{\cdot}9715.$$

When a fluid impinges upon a plane surface in an oblique direction, it will impel the plane in a direction at right angles to its surface with a force which is proportional to the square of the velocity of motion, the density of the fluid, the area of the plane, and the square of the sine of the angle of incidence. The equation for the resistance then becomes—

$$\text{Resistance} = \text{area} \times \text{velocity squared} \times \text{sine squared of angle of incidence} \times 0{\cdot}9715.$$

When a paddle-wheel is first put in motion, every point upon it describes a circle round the centre but as the vessel begins to move, the forward motion of the vessel being compounded with the rotative motion of the wheel, each point describes in the air or water a curtate cycloid differing from a circle in the proportion of its propinquity to the centre. The speed of the vessel is usually about a third less than the speed of the extremities of the paddle-arms, and a circle, therefore, described on the wheel with a radius of two-thirds the length of the paddle-arm, will travel with the same speed as the vessel passes through the water. This circle, which is usually called the rolling circle, is such, that if the vessel were travelling upon land upon wheels of that size, and with the same speed of engine, her velocity would remain unaffected.

As every point in the radius of the wheel moves with a greater velocity as it is further from the centre, it is clear that the portion of the paddle-board furthest removed from the centre must experience a different degree of resistance from the portion nearer to it; and the mean centre of pressure therefore cannot be at the centre of the float, but at a point nearer the outer edge, and varies also with the angle of the paddle and the depth of the immersion. For light immersions it may be reckoned that the resistance on any point of the paddle-board varies as the 3d power of its distance from the rolling circle; and assuming this, we arrive at the following rule: From the radius of the wheel subtract the radius of the rolling circle; to the remainder add the depth of the paddle-board, and divide the fourth power of the sum by four times the depth; then from the cube root of the quotient subtract the difference between the radii of the wheel and circle of rotation, and the remainder will be the distance of the centre of pressure from the upper edge of the paddle. Instead of the common radial paddle-wheel, a description of wheels with moveable floats, known as Morgan's wheels, are now much employed, though they were for many years regarded with disfavor. In this wheel each paddle, which is of iron, is hung upon a centre in the manner of a throttle-valve, and is connected by a rod to a fixed eccentric, either on the side of the ship, or upon the spring beams which sustain the end of the paddle-shaft. When the wheel revolves, the operation of the eccentric maintains every float in the vertical position, or nearly so, whereby a more perfect action of the wheel is realized than if the floats were fixed, as in the case of the common radial paddle with wooden floats.

In considering attentively the action of the paddle-wheel, it will be remarked, that although the circular velocity of the wheel is uniform, very unequal portions of the cycloidal path are described in equal times; for the space described during the first quadrant is more than double that described during the second, and that described during the third quadrant is less than half that described during the fourth. The result of this action is, that the verticle paddle-board, instead of being the most effectual in the propulsion of the vessel, as might appear on a cursory survey, is the least effectual of the floats immerged: for the horizontal velocity of a float, when in the vertical position, is at its minimum point, and consequently in the common radial paddle-wheel both the entering and emerging floats are the more effectual. In the feathering paddle this action is materially modified, and the feathering paddles do not involve the same loss of power. By rendering a smaller diameter of wheel applicable, too, they enable the engines to move at a higher speed, whereby their efficacy is increased: a vessel that will go 13 miles an hour with the common wheels, will make a mile an hour more with the feathering wheels, the power of the engines being the same in both cases.

The screw propeller.—There is too little yet known respecting the performance and manner of operation of the screw propeller to justify the formation of rules pretending to regulate the details of practice; but the conviction of the most experienced engineers appears, at the present time, to be, that while for river steamers the feathering paddle is the best propeller, the screw has, at least, established a claim to equality in the case of ocean steamers; while as a propeller for vessels fitted with auxiliary power it has an undisputed superiority. For vessels of war the screw has the manifest recommendation, that it is less exposed to shot, and the whole of the machinery for driving the screw may be placed under the water-line, which is not possible in the case of paddle-wheel steamers.

The form in which the screw propeller was first applied to the Archimedes steamer consisted of a broad helical feather attached to a cylindrical axis, driven by the engine, and which, working in the water in nearly the same manner as a carpenter's screw works in a piece of wood, carried the vessel forward in the direction of its length. The helical feather made a single convolution round the axis, the length of the convolution being regulated by the pitch of the screw; but this arrangement was relinquished, as it gave a vibratory motion to the boat, interfered with the action of the rudder, and threw the strain too much on one side of the axis; and two half convolutions of a double-threaded screw were adopted, instead of the whole convolution of a single-threaded screw. In later applications the screw has been

made much shorter than what answers to half a convolution; about one-sixth of a convolution is now a common proportion. In the Great Northern, the area of midship section at 16 feet draft of water is 540 square feet, while the screw contains about 90 square feet, deducting the area of the boss. The speed of the vessel is nine statute miles an hour, and the slip of the screw is one-tenth.

If, when the vessel is at rest, the engine causes the screw to revolve on its axis without advancing forward in the water, every point of its surface will describe a circle, the magnitude of which is proportional to the distance of the describing point from the centre of motion. It is clear the surface of the screw will strike the water with a force that is due to the velocity of motion, and the water will be impelled in a direction at right angles to the surface, with a velocity corresponding to that of the revolving feather, but varying in proportion to the distance of any particular point from the axis. This is the force that is effective in propelling the vessel, and it will be seen that it is greater, at a greater distance from the centre, decreasing gradually as we approach the axis where the velocity of the revolving surface is small. On the other hand, if the vessel moves forward in the direction of its length while the screw is prevented from revolving on its axis, every point on the surface of the projecting feather will trace a straight line, equal in length to the distance passed over by the vessel; or, in other words, the screw, in being pulled forward, will displace a cylinder of water of its own diameter and of the length of the vessel's motion, occasioning, of course, a waste of power in the operation. When the screw is put into action by the engine, both of these resistances are encountered. If the action of the propeller were perfect, the screw would operate as if working in a nut; and as there would be then no loss by slip, we could ascertain the speed of the vessel by multiplying the number of revolutions by the pitch of the screw, and dividing by 88, which would give the speed per hour in statute miles; but in practice the speed is generally from one-tenth to one-twentieth less than the speed thus ascertained. There is not an invariable loss by slip, however, or at least not an apparent loss, for in some cases, the vessel is propelled at a faster rate than if the screw worked in a solid. One cause of this anomaly probably is, that the water, in closing in upon the wake of the vessel, having a motion given to it, the screw impinges, not upon still, but upon moving water, whereby an increased reaction is obtained; but something depends too upon the size of the screw, and in general it has been found that when the superficial area of the screw, taken as a disk, is about one-fourth of the area of the immersed section of the vessel, the speed will be as great or greater than if the screw was working in a solid. The water partakes very little of the rotatory motion of the screw, but is drawn in on all sides from the circumference towards the centre, and is then projected aft in a column slightly conical, as it recedes from the screw. The pitch of the screw, or the angle at which the blades are set, differs necessarily with the form of the vessel and the power of the engine; or, in other words, with the speed expected to be attained: a common enough angle is from 66 to 68 degrees with the axis.

In settling the dimensions and pitch of screw proper for any particular vessel, the first indication is to make the diameter of the screw as large as it can be got; and then the probable speed of the vessel, judging from the power and form, is to be estimated, which, after fixing the number of revolutions and making an allowance of say one-tenth or one-twelfth for slip, will give the pitch of the screw. Most of the screws now used are made with two threads, or have two blades. Screws with three blades act more equably, as the whole of the blades are never in the line of the stern-post at once, at which point the forward thrust is greatest; but double-threaded screws seem upon the whole to be the most effective, and they may, if necessary, project beneath the keel, as they can be turned into the horizontal direction when the vessel is in harbor, to prevent them from touching the ground. To ascertain the amount of helical surface of a screw making one convolution, multiply the sum of the radii of the screw and of the central boss by their difference, and the product will be the difference of their squares: multiply this number by 3·1416, and the product by the secant of the angle of the screw, and the result will be the area of the helical surface sought.

Bourne's double-power engine.—The screw propeller has created a new exigency in steam mechanism. The propeller generally requires to make a greater number of revolutions than the engines can conveniently perform; and cog-wheels have in many cases been introduced to bring up the speed, thus introducing into steam vessels the jar, tremor, and liability to fracture incidental to the use of such devices. To remove this source of objection it is necessary that the engines should be coupled direct to the propeller shaft; but as the valves of the air-pumps would strike so hard as to knock themselves to pieces if the engines were worked at any very high speed, and as the various contrivances of canvas and India-rubber valves are of doubtful efficacy in such an emergency, Mr. Bourne has contrived a species of engine in which the whole of the air-pump valves are replaced by a particular arrangement of slide-valve, whereby the engine may be worked at any degree of speed without inconvenience. One effect of this innovation is to make engines work more noiselessly than before, as there is no longer any shock, such as that which attaches to the action of the foot and delivery valves and the valves of the air-pump bucket in common engines. But the most important feature of the arrangement is, that by enabling the engines to work at twice the ordinary speed, it enables them to exert twice the ordinary power. It is not for screw vessels alone, therefore, that such engines are appropriate, but they may be applied with advantage to most of the purposes for which steam power is required. In the case of mill engines they possess the recommendation of imparting a more equable motion to the machinery, and in other cases they may be so arranged as to save fuel by permitting a larger expansion than could be allowed with a lower speed.

The boiler of the double-power engine is for the most part constructed with upright tubes, and the engine set upon the boiler in all powers under 40 horses. The following are the chief dimensions of a one-horse power engine and boiler:—Diameter of boiler, 16 inches; height of boiler, 40 inches; diameter of furnace at crown-plate, 12 inches; diameter of furnace at bars, 13 inches; height of crown-plate above bars, 12 inches; depth of fire-bars, 2 inches; depth of ash-pit, 4 inches; depth of smoke-box, 4 inches; diameter of chimney, 3 inches. There are 36 tubes in the boiler, 1 inch in diameter, and 16 inches long · but 12 inches in the length of tube only passes through the water, and is alone counted as

Rule for finding Horse power of engine

effective: the thickness of the shell of the boiler is three-sixteenths; and the pressure the boiler is calculated to bear is 80 pounds, though 70 pounds is the working pressure. The diameter of the cylinder is 2 inches; length of stroke, 3 inches; number of revolutions per minute, 872; number of feet travelled by the piston per minute, 436; and though these dimensions are small, that they will give fully a horse power is made manifest by a simple calculation. The area of a cylinder 2 inches in diameter is 3·1416; and if the effective pressure be taken at 60 pounds per square inch, instead of 70 pounds, (as a compensation for friction and loss of effect from radiation and expansion,) we have a force of 188½ pounds urging the piston at a speed of 436 feet per minute, which is equivalent to 82,184 pounds raised one foot high in the minute; and dividing by 33,000, this gives us about 2½ horse power. On calculating the amount of tube surface, it will be found to amount to 12 square feet, and the furnace surface will amount to about 3½ square feet more, making a total of 15½ square feet of heating surface per horse power, which is a large allowance. The weight of the boiler is about 2¾ cwt., and the total weight of engine and boiler, with water in the boiler, is about 4¼ cwt.

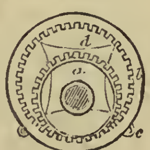
Of the 40-horse power engine and boiler on the double-power plan, the following are the principal dimensions:—Diameter of boiler, 4 feet 8 in.; height of boiler, 8 feet; diameter of furnace at crown-plate, 4 feet; diameter of furnace at bars, 4 feet 1 inch; height of crown-plate above bars, 20 inches; depth of fire-bars, 4 inches; depth of ash-pit, 8 inches; depth of smoke-box, 12 inches; diameter of chimney, 12 inches. There are 547 tubes 1 inch diameter, and 52 inches long, of which a length of 34 inches only passes through the water, and is alone reckoned as effective. The thickness of the shell of the boiler is half an inch, and the plates are all double riveted; the pressure which the boiler is calculated to withstand is 80 pounds. The diameter of the cylinder is 12 inches; length of stroke, 18 inches; number of revolutions per minute, 195; number of feet travelled by the piston per minute, 586. The area of a cylinder 12 inches in diameter is 113·097 square inches; and if we take the effective pressure as before, at 60 pounds, we have a force of 6785·8 urging the piston at a speed of 586 feet per minute, which is equivalent to 3,976,490 pounds raised one foot high per minute, which, being divided by 33,000, gives 120 horses' power, which is just three times the nominal power. The weight of the boilers is about 61½ cwt.; and the total weight of engine and boiler, with water in the boiler, is 90 cwt., or 2¼ cwt. per horse power.

The engine is of the oscillating kind, and the shaft, crank, and framing for supporting the crank, are all of polished malleable iron; the fly-wheel is very small, and is made with a polished rim, which also answers for the drum upon which the belt runs that carries away the power. The governor is made in the usual manner. The waste steam passes into the chimney, as in locomotive engines, whereby the draught is so quickened that a small area of grate-bar suffices; but the end of the eduction pipe entering the chimney is never contracted, as in locomotives. In the larger class of engines a platform is attached to the boiler, to make the engine accessible to the engine-man, thus obviating the necessity of any peculiar structure in the engine-house.

Galloway's direct-action engine.—This engine consists of two steam cylinders, the piston and rods of which are attached by suitable links to a main cross-head or beam, connecting both engines; forming a part of this cross-head are two triangular frames of wrought-iron, which, serving the double purpose of side-rods and connecting-rods, descend one on each side of the cylinders, and they are connected immediately with the cranks on the main shaft, lying between the cylinders in a line with the keel of the vessel. The air-pumps are worked by the same arrangement of levers which forms the parallel motion for the piston-rods; the hot water and bilge pumps are wrought by the air-pump cross-heads in the usual way. The main shaft gives motion to the screw shaft through the medium of a new multiplying geer. The engines are of 300-horse power, and every part of them is below the water line of the vessel.

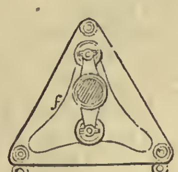
There is extraordinary ingenuity in the whole of these arrangements; nevertheless this engine has not come into use. The mode of operation of the multiplying geer is not easily comprehended, but the principle of the arrangement may be explained to consist in such an arrangement of two cranks, of which the one is twice the length of the other, that the movement of the crank-pin of the longer crank through a semicircle will cause the crank-pin of the smaller crank to move through a whole circle. The principle, however, will be made more clear by an extract from Mr. Galloway's specification, which we therefore introduce.

1473.



1474.

1475.



1476.

"If the wheels shown in Fig. 1474 revolved upon axes in the usual way, *a* would make an entire revolution, whilst *b* made only some portion of a revolution; but if *b*, instead of revolving upon an axis, be suspended upon three cranks *c c c*, of equal length, and the radii of which are respectively equal to one-half the difference between the diameters of the wheels, (calculating such diameters from the pitch-lines;) and if the whole apparatus be at first in the position indicated by the drawing, thereby causing *a* to revolve, it will be found that the cranks *c c c*, and consequently their axes, will make three revolutions during the time that the inner wheel *a* makes one revolution. So if the proportionate diameters differ, say as 2 to 3, or 4 to 5, or any other integral proportions, and the lengths of the cranks *c c c* be determined, then the cranks will always make as many more revolutions than the axis of *a*, as the diameter of the driving-wheel *a* is to the difference between the diameter of the two wheels.

"But I propose, in most cases, as I have stated, instead of using toothed wheels, to adopt the arrangement shown in Figs. 1474, 1475, and 1476, which I shall now explain:—Let it be supposed that three equidistant points, *d d d*, Fig. 1473, could trace their path upon a plate or disk, attached to *b*, and moving therewith, such path would be four epicycloids dotted thereon; and if to the points *d d d*, three rollers, of equal diameter, were affixed, then a figure, *e e e e*, Fig. 1474, would be the tangent of the said rollers in every part of their path; or, in other words, the rollers would trace out the figure *e e e e*, Fig. 1474; such being the case, it will be manifest that if, instead of toothed wheels, we adopt the arrangement shown in Fig. 1474, where *d d d* are the three rollers, affixed to arms, and revolving in bearings, and the figure *e e e e*, whose interior curved aperture is generated upon the principle I have explained—then, on motion being given to the main axis, the cranks, dotted at *c c e*, will make three revolutions for one of the main axis; and if the figure *e e e e* be accurately constructed, and the cranks truly proportioned, the action of the machine will be comparatively smooth and noiseless. In like manner, if the circles or wheels *a* and *b* be in their diameters as 2 to 3, the figure *f f f*, Fig. 1475, would be generated, and by attaching the two rollers to the axis, as there shown, the velocity of the main axis would be to the crank axis as 2 to 1; or, if the diameter of *a* and *b* be as 4 to 5, the figure *g g g*, Fig. 1476, would be generated, and by constructing the apparatus, as shown at Fig. 1476, the relative velocities of the main axis and crank axis will be as 4 to 1. I would further observe, that in whatever proportion the multiplication be effected, it is necessary that the number of the rollers and of epicycloids should be respectively equal to the number of times the generating circles can be divided by the difference between the two diameters. It will also be manifest, that the multiplication effected by this method does not admit of fractional quantities, but must always be in integral proportions. I must further explain, that if one propeller only is intended to be used, one only of the three crank axes must be prolonged for that purpose; but if two propellers are intended to be applied, then two of the crank axes should be similarly prolonged. It is further necessary to explain, that the arrangement of this contrivance may be changed by attaching the driving axis to the epicycloidal figure, and the cranks to the part to which the rollers are attached; in which case the proportion of the multiplication will also be changed, so that the cranks of Fig. 1474 would make three revolutions instead of two; those of Fig. 1475 would make four revolutions instead of three; and those of Fig. 1476 would make five revolutions instead of four." This method of multiplying the speed of the screw-shaft, though most ingenious, is likely to be rendered needless by the acceleration of the speed of the engine itself which is now taking place.

Direct-action engines.—Direct-action engines have of late years come into extended use in steam vessels, and their employment appears likely to become universal. They are less bulky and less weighty than side-lever engines, and although most engineers resisted their introduction, these engines have now, even in the engineering world, risen to considerable favor. Most of the early devices were crude and unsatisfactory, but the excellent performance of the oscillating and double-cross-head engines have redeemed the class from the disgrace that might otherwise have been expected to overtake it. The existing crop of direct-action engines is divisible into five varieties: the Gorgon, Siamese, Steeple, Double-cross-head, and Oscillating.

Many nautical men, and some engineers, have objected to oscillating engines on account of the movement of the cylinder, which they imagined would become a formidable evil in the case of a vessel rolling heavily at sea. These objectors do not seem to have remarked that the rolling of the cylinder is neither dependent upon, nor proportionate to, the rolling of the ship, but is regulated exclusively by the movement of the piston; and it is difficult to see why a mass of matter, in the form of a cylinder, should be more formidable or intractable in its movements than a similar quantity of matter in the form of a side-lever, or in any other shape whatever. It has also been objected against the oscillating engine, that the eduction passages are more tortuous than in common engines, so that the steam gets out of the cylinder less freely. We do not believe such to be the fact, if the comparison be made with the common run of marine engines; and in practice, no diminution of efficacy from this cause is appreciable. The fact is, all the objections that have been raised to the oscillating engine are merely hypothetical; they are anticipations of defects *to be* found out in large engines on the oscillating plan, and would probably be plausible enough to carry some weight, were it not the fact, that they have been completely controverted by experience. The remark, indeed, is heard sometimes even yet, that the oscillating method may do very well for small engines, but is of doubtful efficacy for large ones. But the definition of large engines has been continually changed, to escape the contradiction experience afforded, and that size is, in every case, decided to be large, which just exceeds the size of the oscillating engine last constructed. The grounds of this skepticism, however, are now being fast contracted: and, indeed, experience has now demolished every objection that theory had raised. Some persons have apprehended that it would be difficult in large oscillating engines to obtain sufficient surface of trunnion to prevent the trunnions from heating; yet we have never been able to learn that any heating of those bearings has been found to occur in practice, and it appears probable that any such disposition would be resisted by the cooling effect of the steam passing through them, which, though hot, is of greatly inferior temperature to that of a hot bearing. It does not appear to us, however, that the trunnions may not be made with any amount of surface that is thought desirable.

Rotary engines.—Rotary engines are engines for obtaining a motion round an axis by the direct action of the steam, without involving the necessity of reciprocation. Some of them operate on the principle of reaction, others operate on the principle of impulse; a third kind trusts to the intervention of some liquid to produce the desired effect. It cannot be said that any one of the multitude of rotatory engines yet tried has been completely successful. It is, of course, impossible that we can give any enumeration, even, of the numberless schemes for rotatory engines that have at various times been projected, but we shall briefly describe a few of those which have attracted the most attention.

A rotary engine, designed by Hornblower, is represented in Figs. 1477, 1478, and 1479, and consists of a steam vessel made of cast-iron, of the form of a globe, flattened at the poles Fig. 1479 is a

representation of the parts of the machine which move round within the steam vessel, and Fig. 1478 represents the interior of Fig. 1477, with its lid removed. The pipe A, Fig. 1477, receives the steam from the boiler, to which is connected a valve-box, of any usual construction, by which to regulate the admission of steam. At B the eduction pipe is connected, leading from the upper apartment to the condensing apparatus, and turning in such a direction as may be most convenient for the discharging pump to be wrought by the axle of the engine. D D is a middle part of the steam vessel, furnished with flanges for the purpose of screwing it to E E, and also for receiving the lid; by which means the partition within is secured to its place in the middle of the machine; and the lid may easily be removed for the purpose of rectifying and repairing the internal structure. G is the square part of one end of the axis of the machine, over which is placed a gland H, divided into parts, in order that it may be put on over the square, and properly embrace the round part of the axis. Within this gland is a stuffing-box, for the purpose of keeping the axle both air and steam tight. In one side of the lower apartment of the steam vessel is a small opening, secured by a lid, for the purpose of cleaning that part of the machine.

1477.

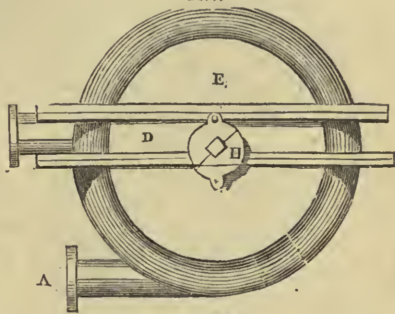
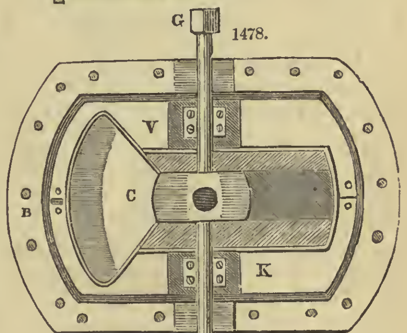


Fig. 1478 represents the partition within the steam vessel, which may be made either of brass or iron, or of both those metals combined. B B is the lower flange, the upper part being taken away. C C are the two openings or passages for the vanes: these the inventor calls vane-ports; and to reach a right conception of their figure, it may be explained, that the largest vane-port is formed by the exterior portions of two cones, and by a portion of the concave part of a sphere. The extent of this passage throughout must at least be equal to ninety degrees of a circle, and the vanes must be of a sufficient width for two of them always to make their entrance into the vane-ports before the other two make their exit. The edge may, therefore, be supposed to descend into the lower apartment one-half of its depth, and to rise the other half to meet the eye. The part E is formed spherically, and is provided with a packing groove, which meets the edge of metal in the middle of the vanes. F F is the main axle of the machine, as well as the descending vane, by which means both the nave and the vanes move steam-tight in their revolutions. V V V V is that part of the partition which forms a plane at the axis of the globe, and is secured in its place by being seated in a rabbet with the usual jointing materials on the interior margin of the steam vessel. Two brasses, G G, are let down into the partition, and they are raised or depressed by screws, as occasion may require. The open vane exhibits a frame of metal, which receives a plate on each side: these plates, with the edge of metal K, cast with the frame, form grooves and vacuities to receive the packing.

1478.



Mr. Samuel Clegg's patent for a rotary engine is represented in Figs. 1480, 1481, and 1482.

1479.

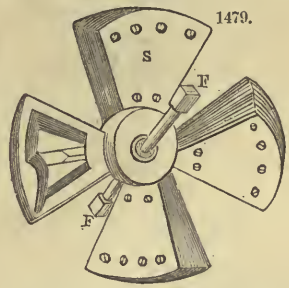
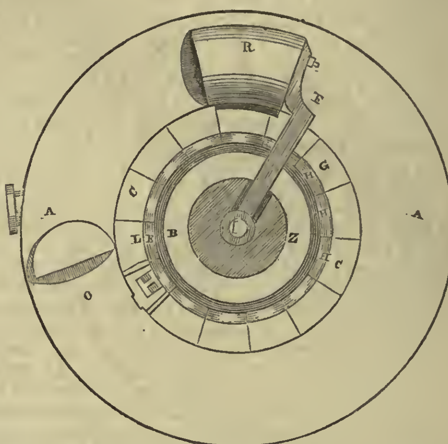


Fig. 1480 is the under side of a circular piece of cast-iron, and of a diameter and thickness proportioned to the size of the engine. I is the common centre of the different circles shown on this piece. With any convenient radius less than that of A A, describe the circle C C, and within the latter the circles D D and E E, the radius of the latter being the least of those now named. From the uses of these parts, which will be immediately described, an idea of their relative dimensions will readily be inferred. Let that part of the surface A B, A B which is contained between the circles A and C, be plain. Between the circles C and D sink a circular groove C D of any given depth; and between the circles D and E let another circular groove be cut, of the breadth D E, and of any given depth less than that of the groove C D. Let the remaining part of the surface A B, namely, that included between E and B, be cut down to any depth less than the depth of the groove D E. Into the groove C D let such a number of segments of a circle be fitted as shall form a complete circle, excepting the space at L, which is occupied by adjusting screws or springs, to keep the segments close together. The segments are the breadth (or nearly) of the groove C D, and of a depth less than that of the groove C D. Those sides of them which apply to each other are to be ground together plain, and air-tight if possible. Their under-surfaces, which are shown in Fig. 1480, are to be flat, so that the whole may form one complete plain surface, excepting the space before mentioned, which is taken up by adjusting screws or springs L, which screws or springs are placed so far below the surface as to let a roller pass by them, which will be mentioned hereafter.

Fig. 1481 represents a vertical section of the plate and grooves of Fig. 1480, resting upon a circular

chamber or hollow space Y Y, to which chamber the said plate forms a light covering, excepting that space occupied by springs or screws L L, as before mentioned. I, the centre of all the grooves and circles before described, is also the centre of the shaft. On the shaft I is fastened a plate or coupling Z, in which is inserted a bar F. This bar may be of any given breadth, but in depth must be less than that to which the circle E B was cut below the surface A B. To this bar is attached a wheel or roller G, shown in Fig. 1482. The manner in which it is attached to the bar F is also there seen, and it is so attached to it that the top of the wheel or roller G shall always be higher than the top of the bar F. The wheel G being attached to the bar F, will, when the bar is made to revolve, describe a circular path H H H, along the plain surface of the segments before described. *c* is the condenser, *a* the air-pump, *b* the air-pump bucket, *d* the hot well, *e* the foot-valve, *f f* the cam which works the air-pump, and *r* a roller resting thereupon. Let that portion of the plain surface of each segment, which answers to the path of the roller G, be rounded off in such a manner as to make that portion of the surface an arc of a circle, the convex circumference of which is presented to the roller G. In Fig. 1482, at H, is shown a perpendicular view of one of the segments, rounded off in the manner described, and presenting its convex circumference to the roller G. There may, likewise, be another roller attached to the bar behind it, to lower down the segments in the same manner in which they are raised by the first roller. Now it is obvious, all the said segments being in their places in the groove C D, Fig. 1480, that the roller G, in performing a revolution round the centre I, must travel along a series of convex arcs of circles equal in number to the number of segments in the groove C D. The groove D E is, in fact, a recess in the deeper groove C D, and may, if necessary, be filled with hemp or tallow, or any other material, which may answer the purpose intended.

1480.



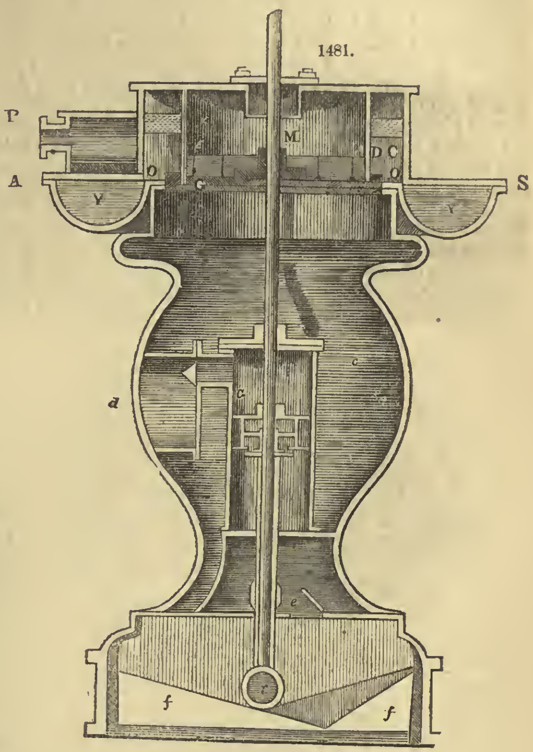
It must be remembered that Fig. 1480 is a view of the under side of the machinery. Fig. 1481 is a section of it, supposed to be in its proper position, resting as a cover to the circular chamber Y Y, and the segments resting upon a flat facing O O. Each segment projects over the facing O O on both sides; their projection on one side completes the cover over the hollow chamber, and the other is the rounded surface for the roller to lift them. The facing O O is exactly, or as nearly as can be, level with the under side of the plate A B A B, when the plate is on its place, as represented in Fig. 1481; so that, when the segments are all in their places, they complete the semicircular chamber, and fit so close on their seats and in the groove, that were the chamber to be filled with any elastic fluid, they would prevent its escape, or nearly, excepting where the space is left for the springs or adjusting screws.

The use of these segments, *which are what the patentee claims as his invention*, is as follows:— Conceive a door or valve to be fitted in the hollow chamber at Q, and a piston R, likewise fitted in the chamber so as to move round in it, and the bar F made fast to the piston, on the side and in the manner represented in Fig. 1480; then, if an elastic fluid of sufficient strength enters the chamber at N, it will press equally against the door-valve and the piston; but the door or valve being immovable, and the piston movable, the piston will be propelled forward in the circular chamber by the elastic fluid. The bar F being fastened to the piston, and the roller G to the bar F, in the manner represented in Fig. 1482; and the roller being in motion with the bar and piston, the roller will lift the segments in succession as it comes in contact with them. The segments before the bar, being by this means lifted, allow the bar to pass; and the operation being the same in all, the bar and piston make a complete revolution. Each segment, as soon as the bar leaves it, falls down by its own gravity, or by springs, or any other contrivance, so that the opening which is made for the bar to pass is closed before the elastic fluid reaches it; the elastic fluid being kept from the opening by the inner breadth of the piston exceeding the outer diameter of each segment. The door or valve is lifted out of the way of the piston, when the piston comes in contact with it, into the opening in the plate at N, a recess being made in that segment which is opposite the door for that purpose; during which time the elastic fluid is shut out, but it enters again when the door returns to its seat, and thus the operation continues. There is much ingenuity in this contrivance: the principle on which the bar is enabled to pass the segments is nearly identical with that introduced by Mr. Clegg into the atmospheric railway, for enabling the piston within the pipe to be joined on to the carriages outside.

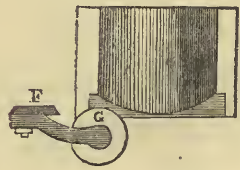
Our next example is Mr. Turner's rotary engine, patented in 1816. Fig. 1483 is a plan of the engine, represented so as to show the internal structure. Fig. 1484 is another plan. Figs. 1485 and 1486 are sections, taken through the axis of the engine in different directions. A A, B B, C C, is the cylinder, or external case of the engine, made in two or more parts, which are fastened together with screws, so as to form a circular or annular passage, the transverse section of which is likewise circular, as shown at E E, Figs. 1485 and 1486. The piston F, Fig. 1483, is accurately fitted into this circular passage, and is caused to revolve therein by the pressure of the steam, which is applied behind it, or on the side F, whilst a vacuum is made before it, or on the side G. The piston being connected with a central plate G, which is fixed fast upon the axis or shaft H, the said shaft is put in motion; and by wheel-work I, or any machinery which is best adapted, the power of the engine is communicated to any useful purposes to which it is intended to be applied. The means by which the force of steam is made to

produce the rotary motion is as follows:—Two valves or sliders, K and L, are applied at the opposite sides of the annular passage or cylinder E E in the manner represented in Figs. 1483 and 1485. The edge of the central plate G, which has the projecting arm to communicate with the piston, must be made so that they can be made to shut up the passage of the cylinder E E, as represented at L, and prevent the passage of the steam through the same, or the slider may be opened, as shown by the dotted lines, to allow the piston F to pass freely through the cylinder. This is done by moving it sideways on its centre 3 out of the cylinder, into the box or case M, which is provided for its reception. The sliders are put in motion by a communication from the outside of the engine, so that each one shall begin to open as soon as the piston F approaches it, and shall be completely opened whilst the piston passes by, and that it shall then descend again upon its seat. N O, Figs. 1483 and 1486, are two passages, through each of which the steam is alternately introduced and withdrawn from the cylinder. The two passages are placed on opposite sides of the centre of the engine, and are provided with valves or cocks, which are adapted to be opened and shut by the action of the machinery in such succession, that when steam is entering from the boiler into the cylinder at one passage, it shall be going out into the open air, or to the condenser, at the opposite passage. The mechanism which actuates the slides K L, and the mechanism which opens the valves for the admission and exhaustion of the steam through the passages N and O, act in concert with each other, and in unison with the motion of the piston F; so that, as soon as possible after the piston has passed by the seat of a slider, the slider shall be lowered down into its place ready to close the passage of the cylinder behind the piston. The instant the piston has passed by the next opening, the steam is admitted to flow through it, and act between the slider and the piston, to force the piston forwards in the cylinder by its expansive force.

1481.

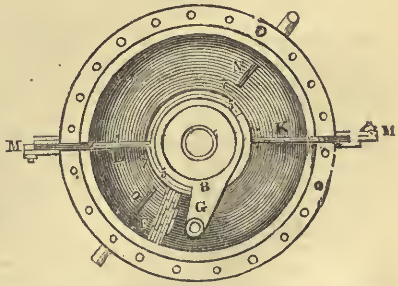


1482.



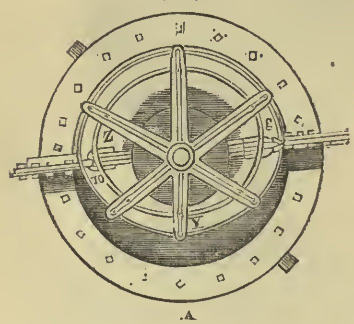
To explain the action of the engine more clearly, suppose the parts in the position in Fig. 1483; the slider L is shut, and the steam is flowing, through the passage O, into the space between the slider L and the piston F; at the same time the passage N is open to the condenser, to exhaust the steam from the remaining part of the cylinder, and to remove the pressure from the front side G of the piston. In consequence, the pressure of the steam acting behind the piston F, puts it in motion in the direction of the arrow, and drives the arm of the central plate before it. The slider K is now in the act of opening, and by the time the projecting part of the plate G arrives at its seat, it will be quite open into the box M, where it will remain until the piston F has passed by its seat; it then begins to descend, and by the time the piston arrives at the opening of the passage N, the slider K will be completely shut and stop the cylinder. The instant the piston has passed over the opening of the passage N, the steam valves are changed by the machinery, so as to admit the steam into the passage N, and also to allow the steam to pass away, through the other passage O, to the condenser; in consequence, the steam enters the space between N and K, and thus, being behind the piston, drives it still forwards towards the slider L, which immediately begins to rise by the action of the machinery, and as soon as the projecting part G of the central plate approaches it, it will have retreated into the box M, leaving the cylinder free for the

1483.

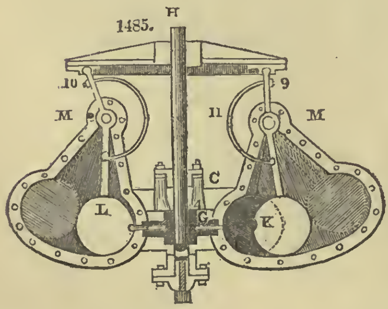


passage of the piston. Immediately after the piston has passed, the slider L descends again, and gets settled to its place by the time the piston arrives at the opening O; and the instant the piston has passed over this opening, the steam valves are changed again; so that the steam will be admitted at O, behind the piston, and act between the slider L and the back of the piston, to force it forwards, which is the same position represented in the figure. By this means the pressure of the steam is always made to act behind the piston, and the vacuum is maintained before it. The sliders K and L are put in motion by levers 9 and 10, which are fitted on the outside of the boxes M, but move upon the same centre pins 3, as the sliders move upon withinside the boxes, the levers being forked, as shown in the figure, to reach on each side of the boxes; and the centre pins 3 pass through the sides of the boxes, and also through both forks of the levers 9, 10, but do not turn round in the holes. To communicate motion from the levers at the outsides of the boxes to the valves withinside, curved rods 11, 11, are carried from the levers through the sides of the boxes M, and jointed to the arm of the sliders; stuffing-boxes are formed round the rods to make tight fittings where they pass through the sides of the boxes M. The ends of the levers 9, 10, are made to be included in an eccentric groove or rein Z Y, fixed to the central axis H. The form of this is shown in Fig. 1484, and is such as to hold the sliders shut, except during the time that it is necessary to lift up the same to allow the piston to pass by. To make the sliders fit steam-tight when they are shut, they are made rather larger than the diameter of the cylinder, and are received in grooves and made round in the inside, and the valves are ground against one of the faces of each of these grooves, so that they will fit tight without any packing. The piston is made of several segments put together, with springs behind them, to throw them out against the inside surface of the cylinder, and it is thus made tight without any packing of hemp.

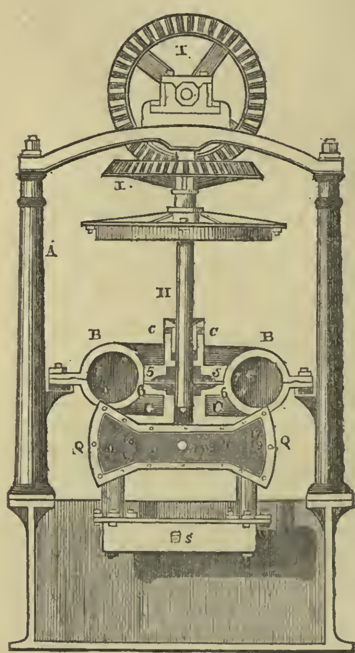
1484.



1485.



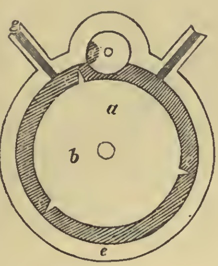
1486.



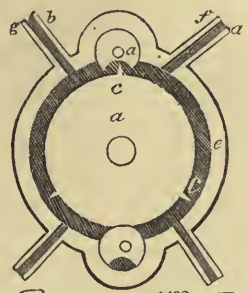
We now come to the patent of Joseph Eve, taken out in 1825. Fig. 1487 presents an end section; Fig. 1488 a longitudinal section of this engine. *a a* are the cylinder and cone, revolving in contact in opposite directions, the cone having one groove, and being one-third of the diameter of the cylinder, which latter has three wings or pistons *c c c*, the ends of which, as they revolve, touch the outer case *e*, and do not admit any steam to pass. The steam is admitted through the pipe *f*, and acting on the wing *c*, causes the cylinder to revolve until the said wing passes the pipe *g*, when the volume of steam lodged betweeen each two wings, is allowed to escape. The wing, which has thus passed, falls into the groove *d* of the cone, the bottom of which groove it touches in passing, thus allowing no steam to escape between. The said wing *c* then passes again by the steam pipe *f*, and is acted upon as before described, and so on in rotation. The cylinder *a*, which is firmly fixed to its axis *b*, rests on one side on the outer case *e*, through which the axis projects; but as there is some friction produced by the revolution of the cylinder at its two ends touching the outer case, a false end *h h* is placed under the opposite end of the cylinder, which false end slides on the axis *b* freely, and has a thread cut at the end, by means of which, and the adjusting nut *i*, the cylinder, if worn at the two ends, can be easily tightened and adjusted. The adjusting nut is confined by the collar *k*, which collar is screwed to the outer case. The conical shape of the small runner, which can likewise be moved upwards or downwards in the outer case, serves to keep the two convex surfaces of the cylinder and cone in contact. The groove *d*, in the conical runner, is cut into a separate piece of metal, which slides by an adjusting screw *o*, up and down:

so that when the engine is adjusted, the groove *d*, on the piece of metal, into which the said groove is cut, can be moved up and down, so as to fit the wings of the cylinder. Letters *n n*, in Fig. 1488, represent two cog-wheels running into each other, attached on the outside of the engine to the axis of the cylinder and cone, placed there for the purpose of producing a corresponding revolution of the said cylinder and cone, thus causing the groove of the cone to present itself regularly to the wings of the cylinder; *o* is a pinion fixed to the other end of the axis, by means of which any machinery can be put in motion

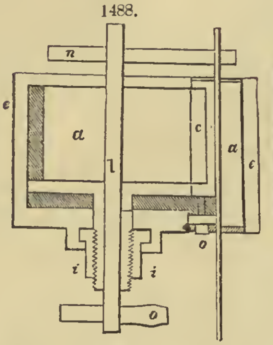
1487.



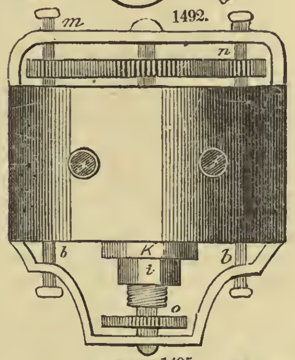
1491.



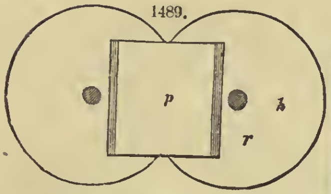
1488.



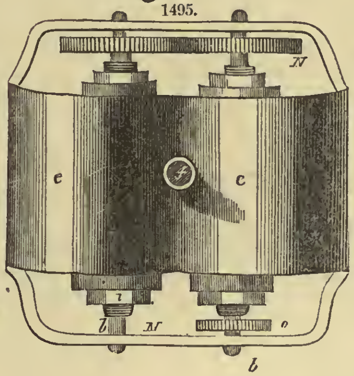
1492.



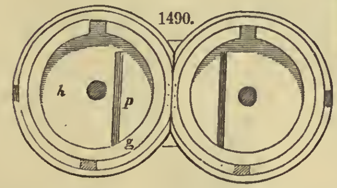
1489.



1495.



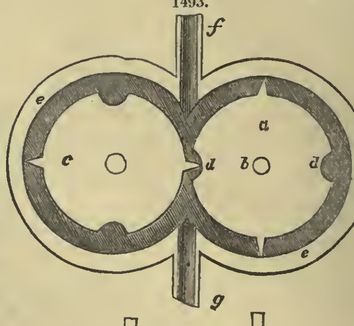
1490.



Another variety of steam-engine on this principle is shown by an end section view in Fig. 1491, and an external view in Fig. 1492. This engine has a cylinder with two small conical runners on each side, the said conical runners being of the same construction as before described, with one groove cut into each, and being one third of the diameter of the cylinder. There are two induction and two eduction steam pipes; and although the engine may be, with the exception of the addition of one of the conical runners, exactly of the same size as the one first described, a double quantity of steam is requisite, and twice the power of the former engine is gained: the steam enters through the pipe *f a*, and acts on the wing *c*, which, after having passed the pipe *g o*, where the steam escapes, falls into the groove *d*, of the lower cone, and appearing at the induction steam pipe *f b*, is loaded again with steam pressure, which it discharges at the second eduction pipe *g o*, and then enters the groove of the upper cone, which having passed, it is loaded again at the first-mentioned induction pipe. Letters *m m* are bridges by which the spindles or axes *b b b* are supported. This engine has three cog-wheels, *n n n*, attached to the three spindles, so as to cause the cylinder and cones to revolve in unison, and, like the first-described engine, has a pinion *o* on the opposite end of the axis of the cylinder. Fig. 1493 shows an end section,

Fig. 1494, a longitudinal section, and Fig. 1495, the exterior of another form of this engine, in which there are two rollers. The conical runners, in this case, are of an equal length and diameter; each has two wings or pistons attached, and two grooves cut into it, and in revolving in opposite directions, the wing of one runner falls alternately into the groove of the other. The steam enters by pipe *f*, and as the cylinders are running in contact, it cannot escape between them, but acts upon the two wings in opposite directions, and escapes at the eduction pipe *g*, after the said wings have passed the same. By reference to Fig. 1494, which represents a longitudinal section, it will be seen that the two cones have each two false ends *h h*, sliding freely on their spindles; the two outer cases *e e*, fit over the runners and their wings exactly; each of the four false ends has an adjusting nut, by which the engine is tightened if steam should escape, or slackened if it should run too tight. Each pair of the false ends, where they join, have a plate that connects them and breaks their joints, so as to prevent an escape of steam; this plate *h* slides into the groove *r*, cut out of the false ends, as exhibited by Fig. 1489 and Fig. 1490, the former showing an end view of the false ends with the connecting plate in the middle. On these false ends packing rings, *g g g*, which are confined to the sliding plate, as exhibited in the latter figure, are placed. These rings press against the hollow outer cases, and prevent any steam escaping by them. These packing rings are shown in section, in Fig. 1494. It will be evident that the false ends need not be made true, if the connecting plates and packing rings, as above described, be adopted, and that the engine, if provided with movable false ends, conical runners, and the afore-described connecting plates, and packing rings attached, as shown in Fig. 1494, can always be kept steam-tight, and by use the various parts, on which there is any friction, will fit better."

1493.



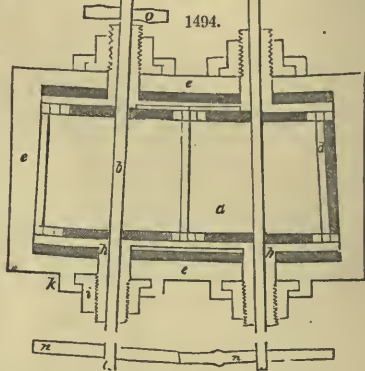
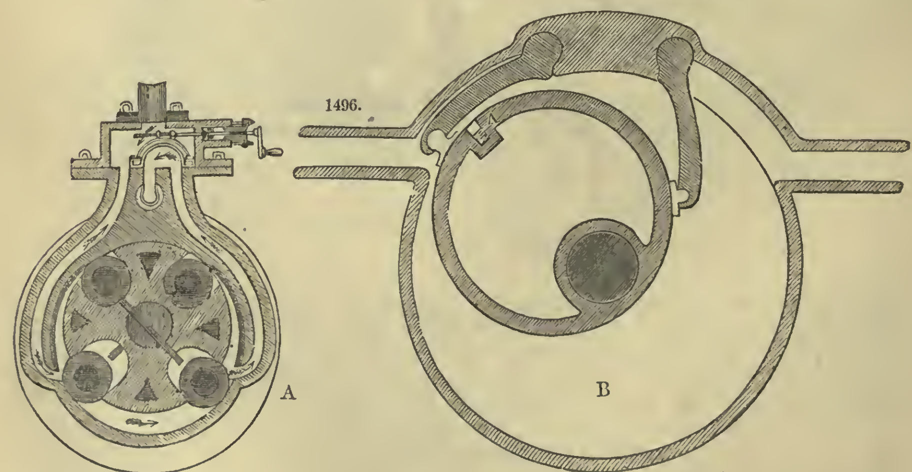


Fig. 1496 (A) is Beale's rotary engine, in which the steam is admitted on the one side of an eccentric frame, armed with rollers, which serve the place of pistons; and the centrifugal force is reckoned capable of keeping the rollers against the interior of the cylinder. An engine upon this plan has been put into a steam vessel, but its success has not been such as to induce its more extended adoption.

Fig. 1496 (B) is the engine specified in the last patent of the Earl of Dundonald, and which has been introduced in the steam frigate "Janus." It is not very correctly represented in the accompanying sketch, which is copied from the rough drawing given in his specification. This plan very much resembles that contrived by Watt, except that an eccentric is substituted for a leaf, and a ball and socket joint is introduced in order to enable the steam and exhaustion

1496.



doors to make a steam-tight junction with the eccentric. This contrivance has not as yet realized any great success, and the prevailing opinion among engineers appears to be, that it will not supersede ordinary engines. Similar engines have been tried on many former occasions, but they have been always found to involve either a ruinous amount of leakage, or such a degree of friction as to make the plan impossible in practice.

1498.

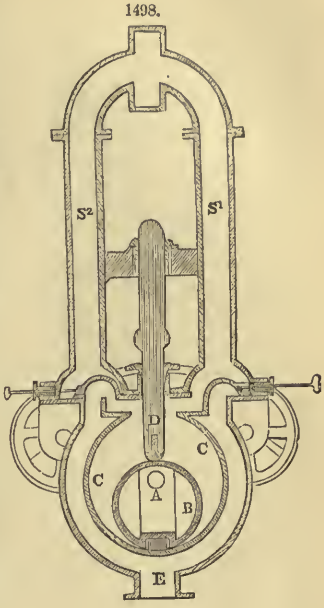


Fig. 1498 is a rotary engine invented by Mr. Yule, and he has had it in operation, working smoothly for some years. It consists of a cylinder C, in which, upon the axis A, revolves another eccentric cylinder B, fitting tightly by means of packing at the line of contact. D is a diaphragm, which slides vertically in strong guides and rests upon the upper side of the revolving piston B. The steam is admitted by either of the pipes S^1 S^2, according to the direction the engine is intended to revolve in, the slide valves at the lower end of the steam pipes being regulated accordingly. E is the eduction pipe. In the figure the steam is represented as entering by the steam pipe S^1, the valve of which covers the eduction port, and admits the steam to press upon the diaphragm D, and the piston B. The steam from the pipe S^2 is at the same time shut off, and the eduction on that side of the piston opened, and there being nothing to counterbalance the pressure of the steam on the other side of the piston, and the diaphragm being incapable of any internal movement, the piston B is made to revolve in the direction of the eduction port. If motion in the contrary direction be desired, it is only necessary to reverse the valves.

Bishopp's Disc Engine, fig. 1497. In order to understand its action, let us imagine a ball A, (fig.[1]), into which the cylindrical rod *c* is inserted so as not to shake laterally. Let the ball be in two halves, between which the disc of card B is firmly held at right angles to the rod A *c*. If its top *c* be carried round the circle *c c*, while the ball constantly occupies the same place, the planes successively assumed by B will change, as if the whole revolved round the imaginary axis *d*. But to resemble the motion of Bishopp's disc, there must be no such actual rotation of the ball and disc, but only of the point *c;* and such a motion of the disc as to make its plane vary and take all the positions of one thus rotating round the axis *d*. Its matter does not revolve, though the space filled by it does; and to imitate this, we must keep the same points of its circumference towards the same points of the compass, notwithstanding the revolution of *c*. Cut a slit *e* along one radius of the disc, and insert therein the piece of card D, fig. [2], having its concave edge cut to fit exactly the ball A; and fix D vertically in one position by inserting it up to the dotted line, between two leaves of a table. Now if the slit *e* be wide enough to slide freely up and down D, and allow the disc to incline itself considerably to the plane of D, we may carry *c* round the circle *c c*, keeping the ball always pressed into the concavity of D, or always filling one position in space, and the disc B will fill the same positions as if it revolved round *d;* every point of its edge becoming successively the highest, and (after half a revolution of *c*) the lowest, although it always keeps the same distance from the fixed partition D, and only moves up and down like each point in a cord along which waves are travelling, or each particle of matter in a real wave. Now, in order to see how the steam imparts this motion, we have only to add two conical surfaces, above and below the disc, as in fig. [3], such that were they complete cones, their points would meet in the centre of the ball A; to fit the surface of which they are truncated, and they may be kept steady by intersecting the plane D. If their inclinations be just equal, it is evident that the disc may be kept in contact with both, one whole radius touching one cone, and the whole of the opposite radius the other cone, perpetually, as *c* revolves. These cones form the two ends or faces of the chamber of the engine, (or *cylinder* as it is commonly called, from the habit of referring every thing to the old form of engine,) and its remaining enclosure must evidently, to fit the edges of the disc in all its positions, be a spherical zone; but this need not be added in order to understand the action. The whole chamber is of course always divided equally into two parts by the disc, and in the two positions where the radius *e* touches either cone, the half on one side the disc (as in fig. [3], that *below* it) is left entire, while that on its other side (in fig. [3], that *above* it) is again divided equally by the fixed partition D, into two quarters of the whole capacity of the zone, although they each occupy *half* its circumference, (as the undivided half does a *whole* circumference, except the thickness of D.) At this moment one of these equal spaces above the disc is in the middle of its connection with the condenser; and in the other, the steam, just disconnected from the boiler, is exerting its expansive power to wedge apart the disc from the cone above, *i. e.* to remove the radius of contact further on, and extend itself from half into the whole circumference, when it will occupy the greatest space which it ever can do, viz. half the zone. And the other space above the disc, (for we are speaking now of what takes place on *one* of its sides only,) the other space will have been reduced to nothing, the touching radius which bounded it behind, having advanced round half a circumference and come to the slit *e*, which is now at the top of the partition D, instead of the bottom. At this instant, then, the whole space above the disc is undivided and full of steam, which at the same moment finds a way opened to the condenser; while the touching radius advancing *past* the partition D, leaves between itself and that partition a small new wedge-like space, into which the steam from the boiler is admitted, and which it speedily enlarges; and when cut off from the boiler, continues to enlarge by its own expansion, as already described; the half filling of this and half emptying of the other space bringing us, by another half revolution of the touching radius, (and consequently of the end of *c*,) round to the position of fig. [3] from which we started. It will thus be evident that the ports for inlet and outlet of the steam, on this side only of the disc, are placed close to the partition D, one before, and one behind it, that the latter may be constantly open to the condenser, as the former

1497.

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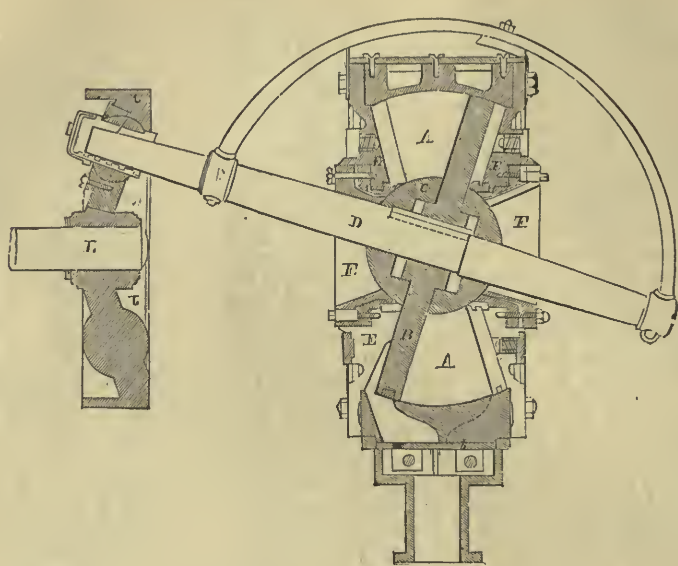

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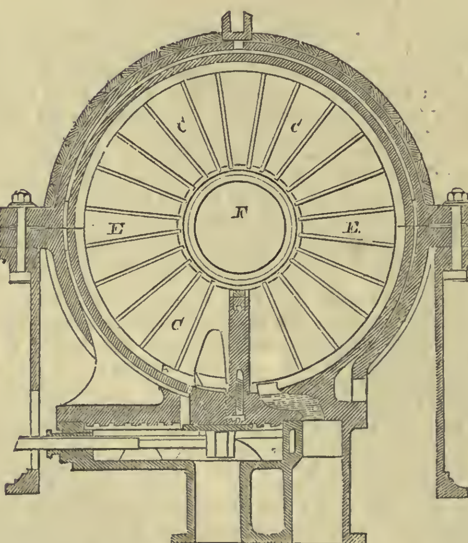

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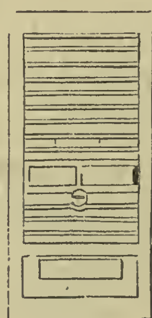

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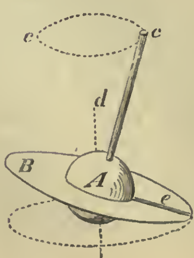

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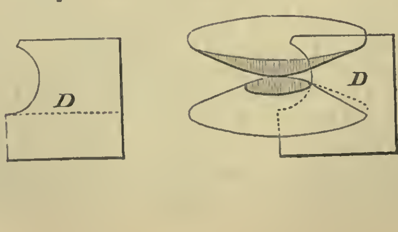


would be to the boiler, were there no expansive working, (which may be carried perhaps more easily to a great extent in this than in any other form of engine,) and that, unlike the single side of an ordinary piston, which is alternately *all* pressed by steam, and *all* left unpressed by its removal, a single side of the disc is only at two moments of the revolution thus exposed wholly to pressure or wholly to exhaustion, and at all other times varying portions of its area to each. All this, of course, takes place exactly the same on the other side of the disc, half a revolution earlier or later, the space on that side being just filled, and replacement by fresh steam just commencing, when the space on this side is divided in halves, one in the middle of enlarging, and the other of being exhausted; so that the utmost moving power derivable on one side occurs when the other is powerless; the arrival of the touching radius at the partition D, (or of the slit *e* at the top or bottom of its stroke,) being a momentary interruption to the action of *one* side only of the piston, whose two sides act independently. And as the surface not pressed on one side the disc equals at every moment what is pressed on the other, the whole area pressed is constantly the same, viz. half the sum of the disc's two faces; so that the motion and power would be perfectly uniform were the pressure of steam so, or were there no expansive working; and the only inequalities arise from its diminished pressure when expanding.

Fig. 4 is a longitudinal section through or near the centre of a disc engine. Fig. 5 is a transverse section of the same, taken also through or near the centre; and fig. 3 is an under plan. A is the steam chamber or cylinder in which the disc B oscillates; C is the ball, which is attached to the disc B.

The American Boat Engine. Its characteristic peculiarities are, the long stroke and velocity of the steam piston, the use of high pressure steam, together with expansion and condensation. A large effective power is thus developed by a machine, the aggregate weight of whose parts is comparatively small.

Nearly all the largest class engines are on the beam plan. Many of the second class and smaller boats have cross-headed, or, as they are termed, *square* engines. In this arrangement the cylinder is situated directly over the paddle-shaft and cranks, to which motion is communicated by side-rods from the cross-head. The air and feed pumps are worked by a separate beam, which is connected with the cross-head by means of appropriate links. There are several examples of inclined and horizontal engines; of the latter kind, two or three of tolerably large size. The John Stevens, now on the Delaware River, and the John Potter, of New York, have steeple engines. With very few exceptions the engines are all single, and are situated in the middle of the boat. In the existing instances of double engines, there are no connecting shafts, but each cylinder works separately one paddle-wheel. In the construction of all these engines, or at least of their framing, wood is largely employed, its cheapness, as well as the facility with which it is worked, being strong recommendations to its use. The engine of the New World, constructed to run on the Hudson River, by T. F. Secor & Co., illustrated in detail in the following figures, is a most perfect example of the river boat beam-engine.

The *Bed-Plate* is a single casting, and forms the foundation of the heavier portions of the engine. It is carefully fitted upon the keelsons of the boat, and is firmly secured by numerous holding-down bolts. That part of the plate which lies between the keelsons forms the channel-way or passage from the condenser to the air-pump. In the centre of this passage are foot valves of the ordinary description.

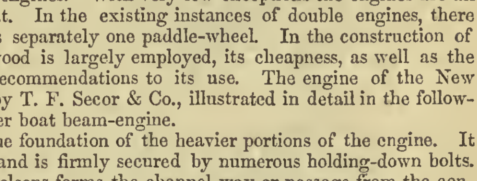
The *Condenser* is of a cylindrical form, flanged at both ends, of the same diameter as the steam cylinder, by 6 feet 6 inches in height; its content is therefore about 13-30th of that of the space through which the piston passes during one stroke. The upper extremity is cast close, the lower end is open, and is fitted down to the chipping-fillets on the bed-plate, to which it is firmly bolted and secured by a rust joint. Near the top of the condenser, and in the front of it, is the exhaust steam branch, a long oblong opening, corresponding to that on the lower steam-chest, to which it is attached. A small branch admits the injection water, which flows upwards through a curved elbow pipe within the condenser. Encircling this pipe, is a circular perforated plate, upon which the water falls in its descent, and becomes dispersed throughout the condenser. On the sides of the condenser, and running in an inclined direction, strongly bracketed webs or flanges are cast, to which the wooden framing that supports the main beam is fastened by bolts and keys.

The *Injection-valves* are of the ordinary conical form, and are worked by screws, which are connected by light spur-geering to hand-wheels, conveniently placed within reach of the engineer. The injection supply-pipes are of copper, and lead directly to the valves from the bottom of the boat.

The *Cylinder-bottom* is a circular flanged casting, containing the lower steam-port. It forms the connection between the cylinder and the condenser, to both of which it is fitted and bolted.

The *Steam-cylinder* is secured to its bottom by a rust joint. It stands vertically over the condenser, and has its upper end steadied by horizontal stays to the framing. Its bored diameter is 76 inches. Fig. 1498 (a) is a section of guide for cross-head, showing the foot which is bolted on the cylinder flange.

1498 (a).



The *Piston* is a hollow casting of iron, strengthened by radiating arms, and also by two wrought-iron bands, which are bored and shrunk upon it. The application of these bands is a recent improvement, by which great additional strength and security are given to the piston. The steam packing is of cast-iron, and consists of three rings, two external, and one internal, whose depth equals that of the other two combined. These rings are all ground to the piston, and to each other. The packing is pressed out by a great number of short elliptical steel springs, which are placed close together round the entire circumference of the body of the piston.

The *Cylinder-cover* is a hollow casting, ribbed similarly to the piston. Its upper surface is turned and polished bright. Circular holes are formed between the ribs, for the support and subsequent extraction of the core, and these holes are afterwards closed with turned stoppers of cast-iron.

The *Steam-chests* are large and capacious castings of iron, containing the valves and seats, and the inlet and outlet steam passages. On the upper chest is cast the throttle-valve pipe, to which is attached the supply steam-pipe, leading from the boilers. On the bottom chest the exhaust branch is cast, through which the waste steam passes to the condenser. The valve-bonnets and glands are turned and polished bright. The chests are rust jointed to the upper and lower steam-ports of the cylinder.

The *Side-pipes*, which connect the steam-chests, are of cast-iron, ornamented with numerous bands and mouldings, and turned and polished bright throughout their entire length. At the upper end of each pipe is an expansion-ring of thin copper, which, by its yielding, compensates for any slight elongation or contraction of the side-pipes, occasioned by heating and cooling.

The *Valves* which govern the entrance and exit of the steam are of a circular form, connected together in pairs, and of the kind called double balance-valves, from the fact that the downward pressure on one valve is balanced, or nearly so, by the upward pressure on the other valve of the same pair. The upper valve of each pair on the steam side, and the lower one of each pair of the exhaust, are a little larger than the others, and, consequently, there exists a small amount of unbalanced pressure, which effectually retains the valves in their seats, and insures their tightness. The valve-seats are formed by boring out the metal of the steam-chests, and the valves are fitted into their places by turning and subsequent grinding with emery and glass-powder. This is an operation requiring great care and skill, as it is absolutely necessary that the valves bear uniformly on both beats, so that there may be no leakage of steam. The taper or cone of the valves and seats is a matter of considerable importance; from ½ inch to ⅝ inch in the diameter, for every inch in depth, is a good proportion. The valves themselves are of brass. The connecting piece of each pair is made of cast-iron, in order to insure, by its expanding uniformly with the steam-chest, the accurate fit of both valves when hot. Engines working in perfectly fresh water have their valves altogether of cast-iron, and in these cases both valves and connecting pieces are cast together; excepting, however, the lower exhaust-valves of each pair, which are kept separately, because, from their larger diameter, they cannot pass through the upper seat, and consequently they have to be introduced either through the steam-port, or through an opening formed in the back of the chest, and then connected with their upper valves.

Where salt water is largely or exclusively used in the boilers, not only the valves but their beats also are made of brass. These are fitted into the chests by turning and boring, and they are then firmly secured by turning over and riveting the under edges, which have been previously rendered thin and sharp, to facilitate this operation. The combined area of the two valves in each pair is about equal to the area of the side-pipe, which is between ⅛th and 1-9th of that of the steam-cylinder. Engines whose pistons move more slowly have proportionately smaller openings for the admission and exit of the steam. The valve-spindles are made either of cast-steel or of the very best wrought-iron. The spindle passes completely through both valves and their connecting piece, and the lower extremity works in a guide, which is a separate casting, bolted to the steam-chest, or when brass beats are used, it is cast with the lower one. The valve-spindles pass upwards through stuffing-boxes in the steam-chest covers to the lifters by which they are worked.

The *Valve-geering* consists of the lifter-rods with their lifters, and the rock-shafts with their levers.

There are four lifter-rods, which are turned bars of wrought-iron, placed in front of the steam-chests. They are made to move vertically up and down through guides which are cast or bolted to the chests and side-pipes. On the lifter-rods are keyed eight projecting arms, called lifters. Four of these embrace the extremities of the valve-spindles, which are screwed, and provided with double jam-nuts. The spindles pass quite loosely through the ends of the lifters, and the jam-nuts are adjusted so as not to bind them: there is thus an allowance made for any slight lateral motion which inaccuracy of adjustment or wear of guides may render requisite. The four remaining lifters are likewise keyed upon the rods, and they are placed directly over the levers on the rock-shafts, from which they receive their motion. There are two rock-shafts, one for the steam and one for the exhaust-valves, and they are worked by separate eccentrics. On the shafts there are four levers, by which the lifters and rods are raised, and they are curved on their working faces, so that their action is rendered perfectly smooth and noiseless. By the reciprocating or rocking motion of the shafts, the lifter-rods, and with them the valves, are alternately raised and lowered. The exhaust-valve levers are of a length just sufficient to give the requisite amount of lift and lead, and they are so adjusted on their rock-shaft, that the moment one rod is fairly down, the raising of the other commences. The steam levers are considerably longer, and are placed upon their rock-shaft in a position inclined to one another, so that an interval, longer or shorter, occurs between the falling of one rod and the rising of the other. During this interval both valves are down, and the steam is of course shut off from the piston. This apparatus then constitutes the expansive or cut-off geering, and it may be varied at pleasure, by simultaneously adjusting the respective positions of the eccentric on the paddle-shaft, of the two levers on the rock-shaft, and of the pin in the eccentric lever. This latter has a slot in it, in which the pin travels, so that it can be moved to or from the shaft, and fixed as required. By advancing the eccentric, and lowering the extremities of the levers, the steam will be earlier cut off, and *vice versâ*. The amount of lift may be regulated by moving the eccentric pin. The movement of the rock-shaft in the interval during which the valves are down is very considerable, especially in a high expansion, and this, added to the additional amount of movement by which the valves are lifted the requisite height, makes the total angular motion of the rock-shaft very great, and therefore an eccentric of corresponding throw is required. The steam eccentric has consequently a throw of 9⅝ inches each way, giving a travel of 19 inches to the rod. The exhaust eccentric throws 5½ inches, giving 11 inches travel. The expansive geer above described is called "Stevens's cut-off," and it is the one employed in the engine of the New World. Another variety of geer in frequent use has but one rock-shaft and eccentric, with but two lifter-rods. The exhaust lifters and their action are precisely the same as in the geer already described. The steam lifters, which are, like the others, keyed to the rod, have spring catches fitted at their extremities, which lock into the valve-spindles when down, and which are released at the proper time, by coming in contact either with an adjust-

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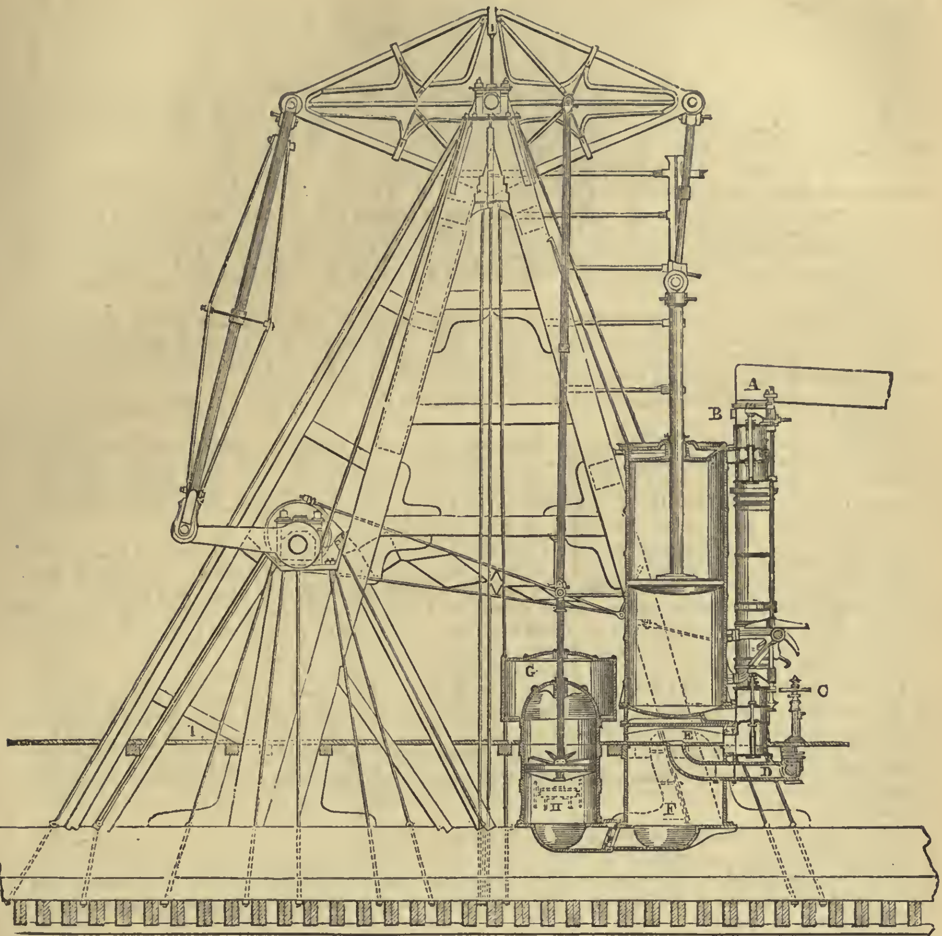

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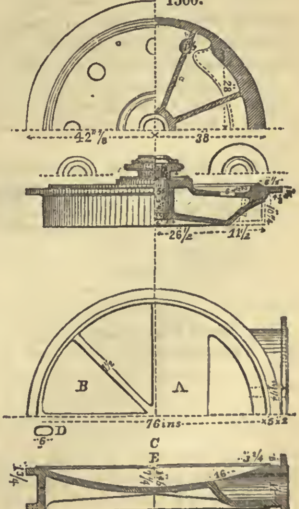

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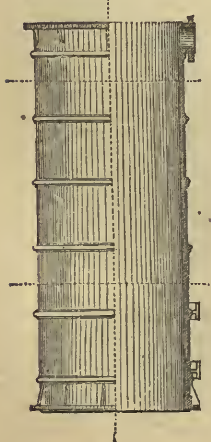

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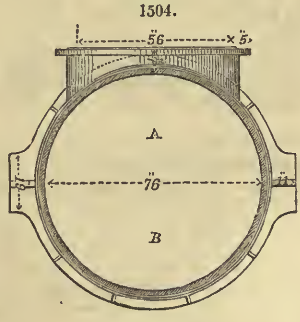

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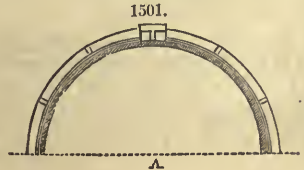

able stop, or with a reciprocating arm, moved by the engine. The valves then fall by their own weight. To prevent damage arising from the concussion, a contrivance called the dash-pot is made use of: this consists of a small cylinder containing water, and a piston which fits it loosely, and is attached to the valve-stem. The height of the water is so adjusted that the piston touches or dashes upon it before the valve reaches its seat: the momentum is thus effectually overcome, and injury to the surfaces of contact completely prevented. The expansion-valve of many of the older engines is simply a throttle-valve, worked by cams on the paddle-shaft. The rock-shaft, lifters, and levers are of cast-iron, turned and finished bright. The outer supports of the rock-shafts are bolted to the side-pipes, and the middle support, which is common to both shafts, is fastened to brackets cast on the cylinder.

The *Hand rock-shaft*, or *trip-shaft*, is a small shaft of wrought-iron working in bearings cast on the lower steam-chest. It has projections welded upon it, corresponding to similar ones on the lifter-rods, and its reciprocating motion raises and lowers the valves precisely in the same manner as in the large rock-shafts. Sockets are formed in the trip-shaft, into which the starting-handle is inserted. The leverage of this is considerable, whilst the resistance amounts to but little more than the weight of the lifter-rods, valves, and their appendages; consequently the handling of the engine is performed with great facility.

The whole front of the engine, consisting of the chests, side-pipes, geers, and the various handles, is highly finished and ornamented, and the profusion of bright work gives it a very showy appearance. Between the side-pipes are placed the clock, counter, steam and vacuum gages, which are very handsomely mounted, and supported by an ornamental framework of cast-iron.

The *Eccentrics* are of cast-iron, turned, bored, and fixed in their places on the paddle-shaft by means of keys and set-screws.

The *Eccentric-bands and rods* are of wrought-iron. The latter are in two lengths, supported at the junction by a pendulum link, which vibrates on a stud fixed to the framing of the engine. The chief portion of the weight of the rod is thus supported, so that the eccentric-hook is very easily disengaged from the pin in the rock-shaft lever. The unhooking geer is a simple arrangement of rods and levers, by means of which the engineer throws out the eccentric-rod hooks.

The *Piston-rod, cross-head, and cap* are of wrought-iron. The guide-blocks, which are of brass, lined with Babbit's metal, are retained by jaws bolted to the extremities of the cross-head. The upper ends of the guide-blocks, projecting above the jaws, are cast hollow, and form very convenient oil-cups.

The *Guides* are of cast-iron, bolted at the bottom to the cylinder-flange, and at the top to a light casting which connects them laterally. Braces of wrought-iron, running horizontally from the framing to the guides, retain them in their truly vertical position.

The *Air-pump* is fitted and bolted to the bed-plate directly behind the condenser; it is of cast-iron, and is lined with brass. The lining is cast in narrow pieces, the edges of which are planed; they are then placed, like the staves of a cask, all round the interior of the pump, which is previously bored out. The last piece is driven in very tightly, and the entire lining then undergoes a severe and continued hammering, by which the metal is condensed, the joints closed, and the brass and cast-iron forced into intimate contact. A second boring completes the pump. The upper flange of the air-pump is made of large diameter, in order to receive the reservoir which stands directly upon it, and is secured to it by a faucet-joint.

The *Air-bucket and valves* are of cast brass. The valves are of the kind called butterfly-valves, and have hinges somewhat longer than the valves which work in corresponding grooves cast in the face of the bucket. The guard which limits the lift of the valves is of brass; it is bored out and slipped over the rod, and bolted down to the bucket. The bucket is provided with a loose junk-ring, fastened with copper bolts.

The *Air-pump rod* is of wrought-iron, sheathed with brass, which is cast around it. Its lower end is turned of a conical form to suit the eye of the bucket, to which it is fastened by a brass key.

The *Discharge* or *delivery valve* is a dome-shaped casting of iron, having in its centre a deep stuffing-box, through which the rod works. A groove is turned out in the lower edge of the valve, and this groove is filled up with wood. This wood forms the beat of the valve, and it works upon a faced ring, cast on the upper end of the air-pump.

The *Reservoir* or *hot-well* is a large cylindrical casting, standing upon the upper flange of the air-pump. It has a cover on the top, with a stuffing-box, through which the rod works.

The *Air-pump cap, cross-head, and guides* are of the same form and construction as those of the steam-cylinder.

The *Feed-pumps* are two in number, and stand on each side of the air-pump, under its broad upper flange; they consist of the barrels, valve-chambers, and buckets, with their rods. The valve-chambers are square castings of iron, which are bolted to projecting brackets cast on the air-pump; they contain the brass flap-valves, to which there are appropriate bonnets. The barrels are plain cylinders of brass, bored out truly cylindrical; they are cemented at the lower end into faucets cast on the valve-chambers, and at the upper end to faucets in the flange of the air-pump. The buckets or plungers are of brass, and are keyed fast to wrought-iron rods which pass through stuffing-boxes in the cover of the reservoir to the air-pump cross-head, to which they are attached.

The *Front links* which connect the cross-head with the working-beam are of wrought-iron, and with their straps, cotters, and brasses, are finished bright.

The *Air-pump links* are similarly fitted up and finished.

The *Working-beam* is composed of a skeleton frame of cast-iron, round which a wrought-iron strap of great strength is fixed. This strap is forged in one piece, and its extreme ends are formed into large eyes, which are bored out to receive the end journals. The skeleton frame is a single casting in the form of a cross, and it contains the eyes for the main centre and air-pump journal. The centre eye is strengthened by wrought-iron hoops which are shrunk upon it. At the points of contact of the strap and skeleton, key-beds are prepared, into which the keys are carefully fitted and tightly driven. The

keys are afterwards riveted over at both ends. By this they are retained in their places, as well as the strap on the skeleton frame. The strap is likewise secured to the frame by small straps and keys. The skeleton frame is still further braced by straps with cotters and gibs, which tie the middle of the long arms of the cross to the extremities of the shorter arms.

The *Beam-journals* are all of wrought-iron, secured in the working-beam by keys.

The *Connecting-rod* is of wrought-iron. It is forked at its upper extremity and single at the crank-pin end. It is stiffened by a double truss-brace of round iron, which is secured by bolts to the rod near each end, and passes over a strut at the centre. This strut is screwed and furnished with nuts, by which the brace is tightened. The rod and its appurtenances are finished bright, in the same style as the front links.

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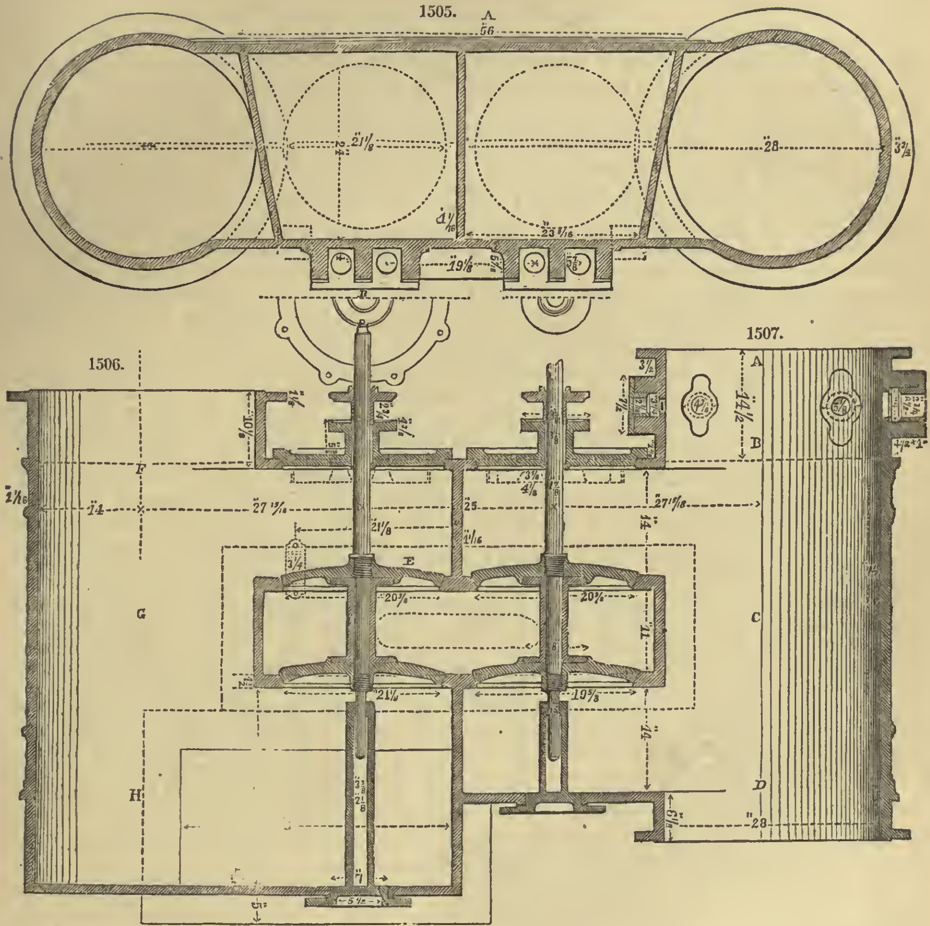


The *Cranks* are of wrought-iron, bored out and shrunk upon the shafts. Cast-iron cranks, strapped with wrought-iron, are very commonly employed on account of their less first cost.

The *Crank-pin* of wrought-iron is keyed fast into a conical hole in the eye of one crank. The other end of the pin is planed square, and passes into a parallel hole in the other crank. In the four segmental spaces thus left between the pin and crank-eye, wedges are fitted, and these are retained in their places by a washer bolted to the end of the pin. This arrangement permits the pin to accommodate itself to any relative motion of the two cranks which the falling of the shaft sooner or later produces: it also facilitates the adjustment of the pin, which is effected by slipping sheet-iron packing under the wedges.

The *Paddle-shafts* are of wrought-iron.

The *Shaft-bearings* or *pillow-blocks* are bracketed castings, formed to suit the angles of the wooden framing on which they lie. They are fitted with the usual brasses, which are lined with Babbit's metal. The holding-down bolts, by which the pillow-blocks are secured, are arranged in a radiating direction from the centre, so that they embrace a considerable extent of the floors and keelsons.

The *Outer-bearings* are simple plummer-blocks, fitted with brasses, and resting on frames which are raised upon the guard-beams.

The *Spring-bearing* is a mere cushion of brass, which is placed to support the shaft just within the wheel, in order to prevent vibration. It is occasionally supported on springs.

The *Pillow-blocks* of the main centre of the working-beam are similarly made with those of the shaft, and are fastened by strap-bolts attached to the wooden framing, and also by bolts extending right down to the floor timbers of the boat.

The *Water-wheels* are made up of the centres, arms, and buckets.

The centres are circular bracketed castings of iron, to which the arms are fitted and bolted; they are bored out to fit the shaft, and secured by eight keys in each. The arms and rims are of wrought-iron, fastened to each other and to the centres by riveting; they are braced laterally by round iron stays, fastened in the form of a cross between the outer arms of each set. There are nineteen sets of three arms in each wheel.

The *Floats* or *buckets* are of wood, and there are thirty-eight in each wheel, attached to the arms by hook-bolts.

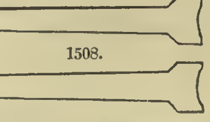
Various forms of wheel are in use: some have the single bucket, as the New World; in others the float-board is divided, sometimes in the direction of its length, and in other cases in that of its width. Iron arms, though much lighter, are more expensive than wooden ones, and are but seldom employed. Wooden arms, moreover, are more readily repaired when fractured by ice, floating timber, or other causes, and such fractures are of frequent occurrence at certain seasons of the year. The divided buckets tend greatly to the smooth and equable motion of the engine, especially in rough water, although the full board will give a somewhat higher speed in water perfectly smooth. The wheels of the New World are the largest ever made, being upwards of 45 feet in diameter.

The *Framework of the engine* is composed of four pieces of pine-wood, which are formed into two triangles, inclined laterally to each other. Their lower ends rest upon the keelsons, and upon their upper extremities are placed the pillow-blocks of the working-beam. They are very solidly fastened together and to the boat by numerous horizontal and diagonal timbers, which are secured by wooden knees and keys, and are heavily bolted. The two front legs of the framing are bolted and keyed to the diagonal flanges cast on the sides of the condenser. At the other end, the framing is attached to the large mass of timbers which support the shaft pillow-blocks. The framing is further steadied by two additional timbers running from the beam pillow-blocks outside the shaft to the keelsons of the boat. The entire fastening of the engine and of its framing is so disposed as to reduce all the strains to direct ones of extension or compression on the fibres of the iron and wood employed in the construction.

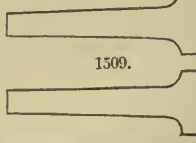
The *Boilers* are on what is termed the single return plan, that is, the flame and heated gases make but one change of direction in their progress from the furnace to the smoke-pipe. The latter is directly over the furnace, at which the flues commence and lead directly to the space or connection at the back of the boiler; from thence another set of flues over the first runs straight to the smoke-pipe. The shell, the upper part of the front, and the flues are all circular, and therefore require no staying. On all flat surfaces, screw, socket, or crow-feet stays, are placed every eight or nine inches apart. The smoke up-take is likewise stayed to the steam-drum by socket-bolts. In the construction of these boilers no angle iron is used, but the plates are everywhere bent to form the junctions at the angles, and the flue-heads are worked out into collars, into which the flues are inserted and riveted. The excellent qualities of the Pennsylvania iron enable this bending to be performed with safety and ease. Except at the junction of the shell and front part, there is no double riveting. With unimportant differences of detail, the great majority of the boilers made and used in and about New York are of the same general form and construction. Tubular boilers on various plans have been and still are occasionally employed, but they have hitherto met with no very extensive adoption. The New World has two boilers, and they are placed on the guards of the boat, abaft of the wheel-houses. The front part of the boilers rests on a bed of putty laid directly on the deck, and the shells are supported by appropriate saddles of cast-iron. The space between the front of the boilers and the wheels is used for the firing-rooms, the coal, and the blowers with their driving engines.

The fuel used is the anthracite coal, and the consumption in both boilers is about 6000 pounds per hour. The durability of the boilers depends very much on the care which is taken of them.

The *Fire-bars* are 1¼ inch wide on the top, with a space of ⅞ of an inch between them; they are cast in pairs, and have a circular groove along their upper surfaces, which, becoming filled with ashes, &c., protects the bar from the extreme heat of the fire.



1508.



1509.

Fig. 1508 is a section of fire-bars of the Georgia and Ohio, burning anthracite coal. Total grate surface, 416 square feet; steam, 15 pounds per square inch; consumption, 5000 pounds weight per hour in the four boilers.

Fig. 1509 is a section of fire-bars of the New World, burning anthracite coal. Total grate surface, 221 square feet; steam, 20 to 35 pounds; consumption of coal per hour, average 6000 pounds.

The *Blowers* are of the direct-action kind, that is, are worked directly on the shafts of their engines, and they are consequently of much larger diameter than those whose speed is got up by pulleys and belts. They are made precisely in the same manner as a paddle-wheel, having cast-iron centres, wrought-iron arms, and wooden buckets, all of course of very slender proportions, answerable to the nature of the work they perform. The casing of the blowers is made of wood, and the air passes through wooden conduits under the fire-room floors, to the ash-pits, which are furnished with suitable doors of wrought-iron.

The *Blower engines*, of which there is one to each boiler, have 14-inch cylinders, by 14 inches length of stroke; they are very simple and compact direct-action engines, and are bolted to perpendicular posts which are fixed to the deck; they receive their steam from the boilers, and exhaust into the condenser, by which the benefit of the vacuum is obtained. The handles of the steam regulators are

placed within convenient reach of the firemen, who can thus start or stop the blower engines, increase or diminish their speed at pleasure, and to suit the varying requirements of the fires.

The *Safety-valves* are of the usual description, with levers and weights; they are eight inches in diameter, and there is one to each boiler.

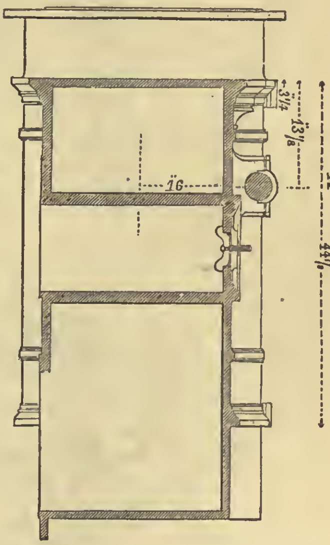
The *Pipes* round the engine, both steam and feed, are of wrought copper, with cast flanges.

The dimensions of the New World are,

	Ft.	In.		Ft.	In.
Length	375	0	Breadth	36	0
Breadth over guards	69	0	Depth of hold	10	6

She is constructed of wood. There are some good examples of iron boats, two or three of them of considerable size. The external planking is 3 inches in thickness, and the ribs are sheathed internally, for a considerable distance amidships, by double-crossed diagonal planking. Further forward and aft, the sheathing is single, and towards the ends of the boat the ribs are not sheathed. The floor timbers are strengthened by several longitudinal timbers or keelsons of considerable size. To compensate for the want of depth in the sides of the boat, the "hog-back" or "bow" frame, is applied to strengthen it. This consists of timbers joined together in the shape of a bow, springing from the side at some little distance from each end of the boat, and rising to a height of 20 or 25 feet at the centre. It is braced to the side in several places by vertical and diagonal timbers and bolts. The whole forms a powerful trussed framework, which is placed directly over the side of the boat, and is to be regarded as being virtually an addition to the depth of the side. The floor of the boat is strengthened by a system of bracing, consisting of masts 40 or 50 feet in length, which are slipped on the keelson, and are furnished at their top with caps, to which are fastened iron rods: these rods radiate to the sides of the boat, like the shrouds in a ship, and they thus transfer the upward pressure on the centre of the floor directly to the side. The deck beams project over the sides of the boat to the extreme width of the wheel-houses, forming what are called the "guards." These guards are supported by diagonal struts underneath them, and they overhang at the centre 16 feet 6 inches; they meet in a point at the bow, and at the stern project about 2 feet 6 inches, forming a gangway round the ladies' saloon. The New World being a day boat, has of course no sleeping berths. The entire space below deck, with the exception of that occupied by the engine, is devoted to two immense dining-saloons. On the after-part of the main deck is the ladies' saloon, nearly one-fourth of the length of the boat. Over this is the hurricane deck, which extends nearly to the bow, and forms a magnificent promenade. The space underneath this deck, forward of the ladies' saloon, is appropriated to the baggage, &c., and on each side of it are rooms for the accommodation of the officers and crew of the boat. The fittings and decorations of the saloons are most costly and magnificent. The night boats have three tiers of berths running completely round the saloon under the main deck, and there is another saloon upon the hurricane deck, extending entirely over it. Opening into this saloon, and on each side of it, are state-rooms containing berths. These night boats thus possess sleeping accommodation for many hundred passengers. The passage from New York to Albany occupies on the average about 9 hours: the total distance is 146 miles. The boats usually make 13 landings, which involve a loss of time of at least 5 minutes each, leaving 7 hours 55 minutes as the average running time, giving a speed of about $18\frac{1}{2}$ miles per hour: this is, however, by no means the top speed, since the passage through is frequently made in much less time. Upwards of 20 miles per hour is commonly effected, and when racing, the swifter boats have occasionally moved at the tremendous rate of at least 22 miles per hour through the water.

1510.

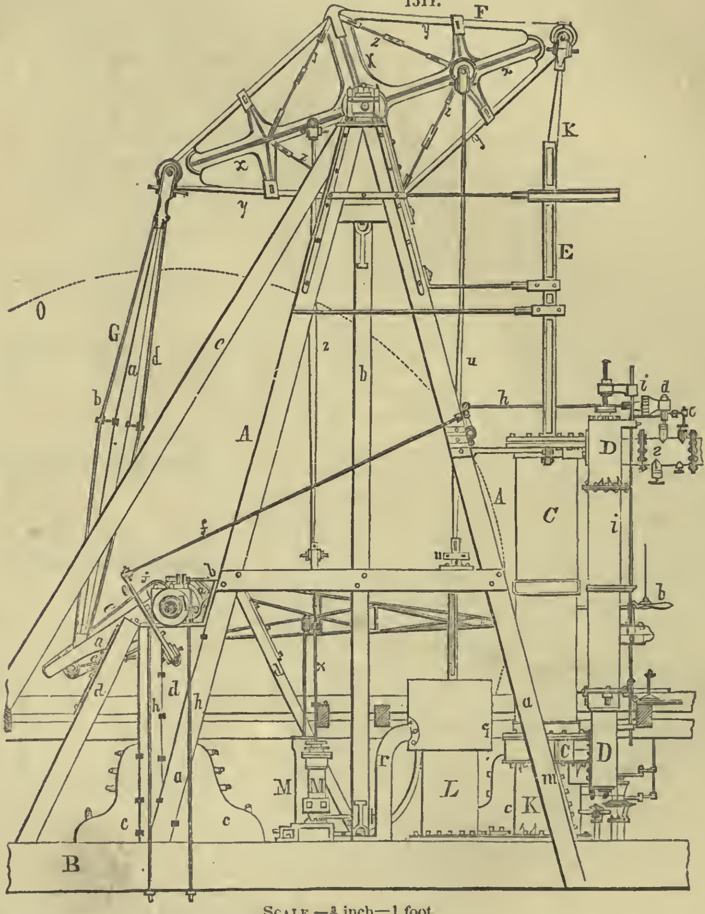


Details of the engine of the Osceola.—As another example of American steamboat engines, we have selected the engine of the steamboat Osceola, made by Adam Hall, of New York, and represented in Figs. 1511 to 1534. The frame is made of yellow pine, well jointed and bolted together, the mortises and tenons being well inlaid with white-lead. The timbers which sustain the crank-shaft bearings are firmly dowelled and bolted to the fore-leg of the main frame, and are further supported with large knees of oak, firmly secured to the keelson. The prevailing and American characteristic in the construction of the engine consists in the free use of tension-rods and straps of wrought-iron, arranged diagonally so as to receive and sustain the alternate strains to which the moving parts are subjected. The advantage of this principle of construction is very obvious, as it renders the parts extremely strong and rigid, at comparatively a small expense of material. This will appear from the description which follows. The arrangement of the working parts is simple and efficient: the handles for starting, stopping, and the injection, being brought to one spot behind the cylinder, thus enabling the engineer to attend instantly when required. The arrangement by which the eccentric-rod is supported on a vibrating rod, renders the working of the engine much less laborious than without it; and by using the balance-valves instead of the ordinary poppet-valves, a very moderate degree of manual force is requisite to work the engine.

Fig. 1511 is a side elevation of the engine. Fig. 1512 is an end elevation, exhibiting the steam-chests, the cylinder, and the parallel motion. Fig. 1513 is a vertical section of the steam cylinder, the condenser, the bed-plate, and the air-pumps. Fig. 1515 is a plan of the bed-plate, showing the passage connecting

the condenser with the air-pump, and the opening by which the foot-valve is introduced to its place. Fig. 1516 is a transverse section of the steam-chests, showing the arrangement of the balance-valves. Fig. 1517 is a plan of the steam-chest, and of the cylinder with the lid removed. Figs. 1518 and 1519 are views of the traverse shaft for working the valve-lifters. Figs. 1520 and 1521 are face and edge views of the crank, showing the method of binding it by a wrought-iron strap. Figs. 1522 and 1523 are front and side views of the connecting-rod, with the method of bracing it by wrought-iron rods. Figs. 1524, 1525, 1526, and 1527, are elevations and plans of the crank-shaft and main centre pedestals, showing the attachments for securing the blocks to the framing. Figs. 1528 and 1529 are an elevation and a plan of one of the paddle-wheels of the steamboat North America. We give this wheel as an example of American paddle-wheels, and of the modes of framing timber for the support of the journals of the paddle-shafts. Fig. 1530 is a front view of one of the floats; Fig. 1531 is an edge view; and Fig. 1532 is a plan. Figs. 1533 and 1534 are a face and edge view of one of the centres of the wheel.

1511.



SCALE.—¾ inch=1 foot.

The following are the literal references:—

A, is the principal frame, which supports the main centres of the beam, and also the bearings of the crank-shaft.

B, are the keelsons.

a a, the fore and aft legs of the frame.

b, the upright post under the main centre.

c, oak knees, by which the legs are secured to the keelsons.

d, timbers which support the crank-shaft bearings; the fore and aft timbers are placed obliquely to strengthen the support.

e, the back-stay for further securing the main centre.

C is the steam cylinder, and C′ is the cylinder bottom.

f, the piston; the under side of it, 1, is a solid web, rounded and in one piece with the centre, 2, by which it is keyed to the rod, and with the circular flange, 3, at the circumference, upon which the packing is laid. These three parts are connected together by stiffening flanges, 4; and the whole is covered in by a flat plate, 5, which holds down the packing, and is bolted to the body of the piston.

g, the piston-rod.

h h, the steam ports; the under port is formed in the cylinder bottom. This, it will be observed, is hollowed out to the form of the under side of the piston.

i, the clutch and cross-head, keyed to the upper end of the piston-rod.

k, the links connecting the cross-head to the working-beam.

D, are the steam chambers, in which are placed the valves for regulating the motion of the steam into and out of the cylinder.

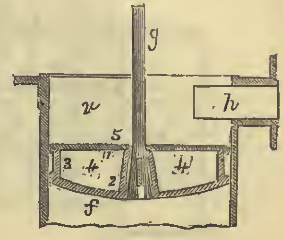
l l, the chambers whence the steam is admitted to the cylinder.

m m, the chambers into which the steam is discharged from the cylinder.

n n, pipes connecting the upper and under chambers; bolted fast to upper chambers, but connected to the under chambers by expansion joints.

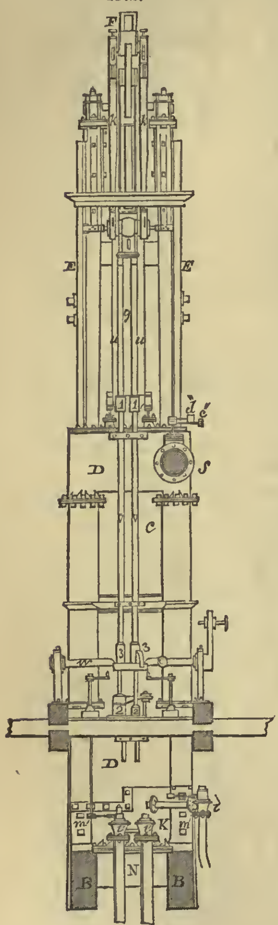
o, the steam-valves, and *p*, the exhaust-valves, fixed in pairs on the spindles, and denominated equilibrium or balance valves.

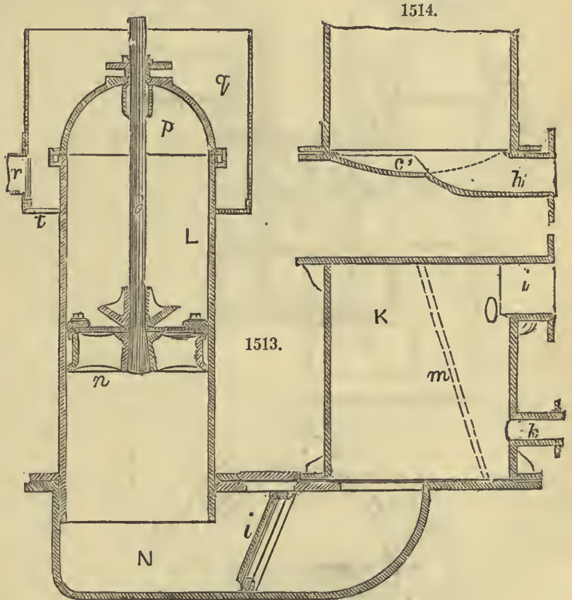
q r, the valve-spindles, having their under ends guided in inverted caps, introduced through the under sides of the steam-chests; their upper ends pass through stuffing-boxes, and are connected on the outside to the brackets on the lifting-rods.



1514.

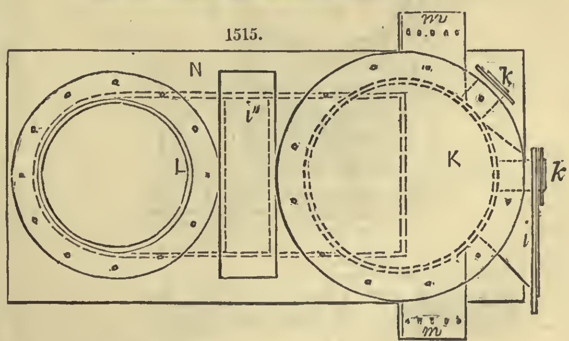
1512.





1513.

1515.

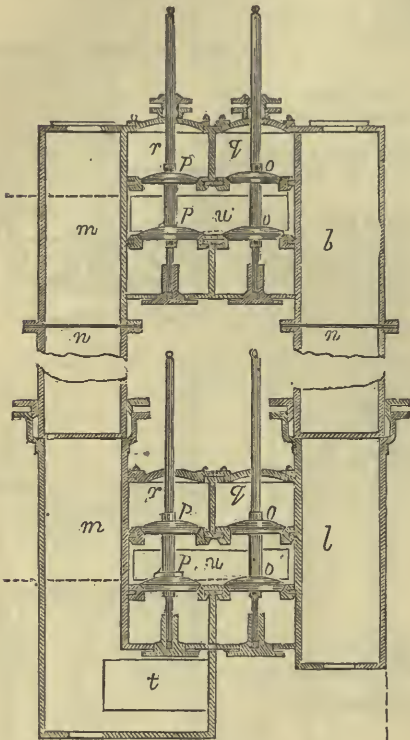


SCALE.—1½ inch=1 foot.

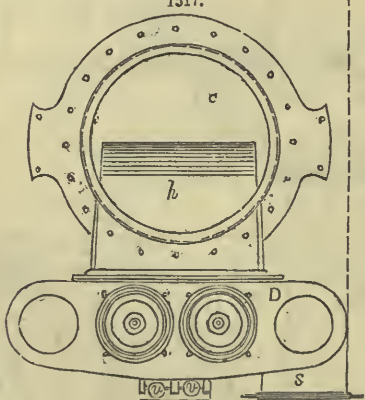
s, the steam-pipe from the boiler. It is furnished with two valves; one of them c'', is the throttle-valve; the other d'', is the cut-off valve; the latter is worked by a cam fixed on the crank-shaft, which works the lever e'', the fulcrum of which is fixed on the timbers of the crank-shaft bearings; this lever working the lever on the valve-spindle by means of the rod f'', the traverse-shaft and levers g'', and the rod h''.

t, the exhaust-passage, connected to the passage i', in the condenser.

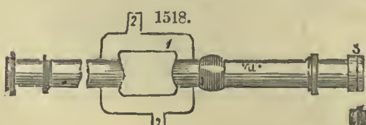
1516.



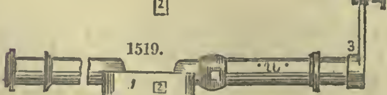
1517.

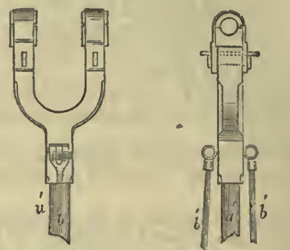


1518.



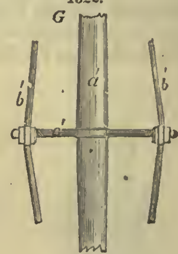
1519.

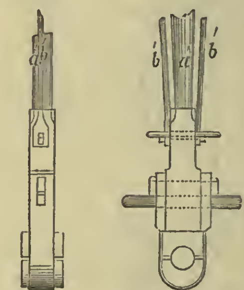




1523.

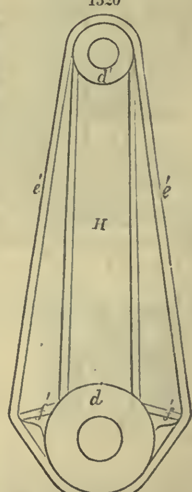
1522.





1521.

1520

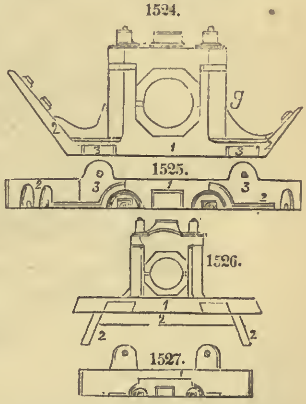


u u, the steam passages to the cylinder.

v v, the lifting-rods, with brackets, 1, 1, 2, 2, fixed on them, and connected at the extremities to the valve-spindles, on which they are adjusted by nuts; 3 3, the lifting faces.

w, the traverse-shaft; 1, the lifting-frame; 2, the lifters; 3, the eccentric-rod lever. (See Figs. 1518 and 1519.)

We may take this opportunity of describing the operation of the balance-valves, and of pointing out the peculiar advantages of them. Referring to Fig. 1516, it will be observed that the valves are arranged in pairs, keyed on distinct spindles, and that each pair, therefore, is moved as one valve; further, the valves in each pair are of unequal diameters, the upper valves *o*, on the steam-side, being larger than the under valves, and, on the contrary, the under-valves *p*, on the exhaust-side, larger than the upper ones. And here the peculiar and elegant adjustment is shown. The common poppet-valve sustains the full pressure of the steam on its exterior surface, which must, therefore, be overcome before the valve can be opened; but, in the balance-valve the steam pressure is made to balance itself, (hence the name,) as it enters the steam port from both above and below. The upper valve in each pair on the steam side is larger than the under by as much as will afford, by the difference of pressures upon them, sufficient force, in conjunction with the weight of the valves, to shut them steam-tight in their seats. *Vice versa*, the *under* valve in each pair on the exhaust side is the larger of the two; that by the resulting tendency of the pressure of the steam from *within*, when entering the cylinder through the steam-valve, the exhaust-valve may be kept shut when required.



1524. 1525. 1526. 1527.

Thus, it is clear that by regulating the relative diameters of the valves in each pair, the absolute difference of the areas of surface of each, exposed to the steam pressure, may also be regulated; and, consequently, also the amount of pressure effective in shutting them. In the present instance, the valves are 10 inches and 9 inches respectively in diameter; therefore, the steam pressure effectively exerted in shutting them is that due to a surface equal to the difference of these areas, or to 15·2 square inches. Let the steam pressure be 50 lbs. on the inch, then the acting pressure will amount to $15{\cdot}2 \times 50 = 760$ lbs., or, the weight of the valves being added, say 840 lbs. This will, indeed, appear little when it is considered what a common poppet-valve would require. If the poppet-valve were 11 inches in diameter, it would be subject to a pressure of 4750 lbs. The slides, also, such as are used in British engines, weigh 3920 lbs., without the friction of the faces being taken into account. But, in fact, as the starting lever has a power of 6 to 1, the resistance to be overcome by the engineer in starting is only 140 lbs.

E are the parallel guides for the cross-head of the piston-rod. These, the cross-head, and the links *k*, constitute the parallel motion of the engine. The guides E are bolted to the projections on the cylinder flange, seen in Fig. 1517, and are stayed to the frame A, by wrought-iron ties, and a small cast-iron cornice near the top. See Fig. 1511.

F is the main lever of the engine.

x, a cast-iron centre, strung with tension-rods.

y, tension-rods of wrought-iron, which are strapped to the centre piece at the middle, the extremities, and the intermediate points.

z, additional tension-rods, strengthening the intermediate points where the air-pump and force-pump rods are connected.

The main centre pedestals are represented in elevation and plan in Figs. 1526 and 1527. 1, the sole; 2 2 2, flanges for securing the bearings more steadily to the frame.

G, the connecting-rod constructed of wrought-iron.

a′, the rod, fitted with straps at the ends for embracing the bushes.

b′ b′, tension-rods for stiffening the main rod, and preventing the effects of vibration. These rods are jointed at the upper ends to the main rod; held in tension at the middle by the strut *c′*, which is screwed and nutted at the extremities to regulate the tension of the rod; and keyed up at the under ends.

H is the crank, composed of a cast-iron body, and a wrought-iron binding strap.

d′, the cast-iron centre, in which the holes are formed for receiving the ends of the crank-shaft and the crank-pin. Its form in section is that of a web terminated on both sides by flanges.

e′, a wrought-iron tension-rod in one piece, passing entirely round the crank.

f′ f′, *horns* cast upon the crank for the purpose of stretching the strap *e′*, the strength being thereby rendered available.

The fellow of this crank, which is seen in the general elevation, Fig. 1511, is differently formed, being made solid at the end, and provided with bolt holes, through which a strap embracing the crank-pin is introduced and screwed upon the other side. By this arrangement, the crank-pin may at any time be readily disengaged from the crank, and the parts are more easily put together.

I is the crank-shaft.

g′, the plummer-block. 1, the sole of the block resting on the timbers; 2 2, flanges for securing the block to the framing by bolts and nuts; 3 3, snugs cast on the sides of the sole, through which holding-down bolts are passed, which are secured to the keelsons.

a″, the eccentric for working the balance-valves.

b″, the eccentric-rod, having its length divided, at a point near the handle, into two parts jointed together, the longer and heavier part next the eccentric being supported on a vibrating joint. By this

means it becomes an easy matter to disengage the rod from the lever of the traverse-shaft; which › done by means of a small rope attached to the extremity of the rod.

K is the condenser.

i′, the exhaust-steam passage.

k′, the injection passages.

l′, the injection cocks.

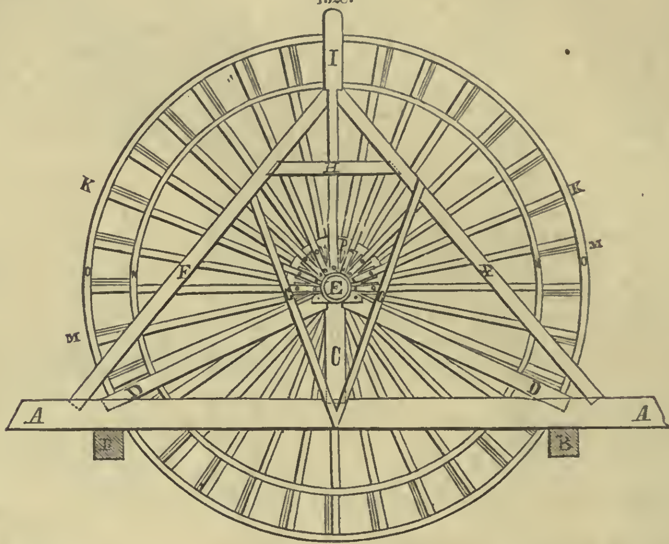
m′ *m*′, the flanges by which the condenser is bolted to the principal frame.

L is the air-pump.

n′, the bucket, the construction of which is obvious from the section, Fig. 1513.

o′, the bucket-rod.

1528.



p′, the delivery valve, which is cast hollow, and has its lower edges, where it rests on the air pump filed true, so as to fit and form a good joint. This serves a two-fold purpose, namely, as the air pump lid and the delivery valve. Its action is simple and ingenious; for when the bucket arrives at a certain height, the lid is raised and the water flows out all round, thus discharging more effectually and rapidly than by the common valve, and requiring little or no power to discharge, having only the lids to raise.

q′, the hot-well, made of copper, and riveted to the air-pump by means of a vertical flange.

r′, the waste-pipe.

s′, the feed-pipe.

t′, the pipe for drawing off the water from the hot-well.

u′, the rod from the beam, which drives the air-pump rod.

v′, the guide for the cross-head of the air-pump rod, staid to the principal frame by means of the bracket *w*′.

M is the force-pump.

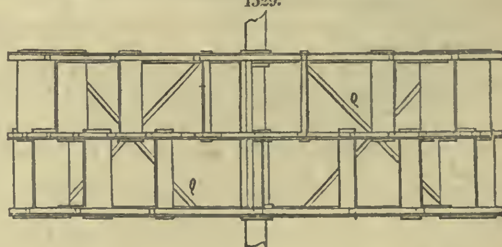
x′, the pump-rod, moving in the guides *y*′ *y*′, driven from the beam by the rod *z*′.

M′ is the bilge-pump.

N is the bed-plate.

i″, the foot-valve.

1529.



The principal dimensions of the Osceola are these:—

Diameter of cylinder	31 inches.			
Length of stroke	11	feet		
Length of beam	17	"	9	"
Length of connecting-rod	21	"	1	"
Lengths of links	7	"	6	"
Height of beam, from keelson	31	"	0	"
Width between guides of piston-rod	3	"	6½	"
Diameter of paddle-wheel	28	"	0	"
Number of strokes per minute	24			
Velocity of piston in feet per minute	528			

The paddle-wheel, of which we have represented the construction in Figs. 1528—1529, is the wheel, 30 feet in diameter, of the steamboat North America.

Fig. 1528 shows the outside framing of the paddle-box, or, as it is frequently termed, the wheel-house; also an elevation of the paddle-wheel, showing the arrangement of the buckets, arms, centre-plate, &c.; A A is the main waling which rests upon the transverse timbers B B, which project from the side of the vessel. C, the main upright on which the outer bearing of the paddle-shaft E rests; D D, diagonal framing for rendering the upright C steady, and also for completing the truss formed by the four pieces. G G, two lighter diagonals quartered into F F, which are mortised into A A, and firmly bolted together with I; the foot of I is mortised into H, which acts as a tie to confine the pieces F F to their places, thus forming a stiff framework for the planking of the wheel-house, and supporting the outer end of the shaft.

K K K are the arms; L L, battens by which the floats are attached to the arms; M M, the float boards; N an inner ring of segments of wood for the purpose of staying the arms; O, an outer ring of iron for further security; P, the centre-plate.

Fig. 1529 is a plan of the paddle-wheel, showing the arrangement of the floats, which gives this kind of wheel the name of "split bucket," and also showing the diagonal bracing Q Q, for the purpose of preventing vibration in the wheel.

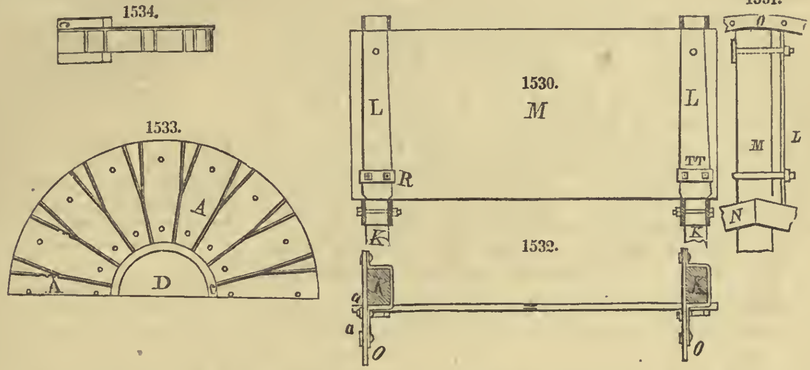


Fig. 1530 is an enlarged view of one of the floats, showing the method of fastening the same to the arm. K K are the arms, three inches by six deep, of red pine; L L, two battens of hard wood placed on the face of the float to retain it more firmly against the arm when the motion is reversed, above $5\frac{3}{4}$ inches wide at one end, and 4 inches at the other, and one inch thick; the float-board M, is 5 feet 3 inches long, 2 feet 4 inches wide, and $1\frac{1}{2}$ inch thick; it is fixed to the arms K K, by means of straps passing round the arm, through the batten L and washer R, and held to its place by $\frac{5}{8}$ screws and nuts, as shown in Figs. 1513 and 1515; it is also held by two $\frac{3}{4}$-inch bolts and nuts at T T.

Fig. 1531, a side view of the method of attaching the same.

Fig. 1532 shows the method of connecting the outer ring to the arms; *a a a* is a strap of iron, half an inch thick and three inches wide, which goes round the arm K, and by being riveted tight to the rings O O, keeps the arm steady in its place.

Fig. 1533 is an elevation of part of the centre-plate, showing the arrangement for fixing the arms. A A A is a plate with webs cast upon it, 16 in number, and at B they diverge to the periphery of the plate, thus forming 16 spaces 6 inches wide, and 16 smaller ones. In the wider spaces, holes are drilled or cast for receiv ng the $\frac{3}{4}$ bolts, which are used in fixing the arms to the plate. D is the hole in the centre, 14 inches diameter, by which the wheel is fixed to the shaft; C is the ring which is made 2 inches thick and $7\frac{1}{2}$ wide, for the key-seats. The plate A is one inch thick, as are also the webs B B.

Fig. 1534 shows the thickness of the plate and the width of the boss or ring C.

Pistons.—By presenting a somewhat heterogeneous and unselected enumeration of the principal varieties, just as they have occurred to us in practice, and noting their respective characteristics, whether merits or defects, we may, perhaps, make our account more instructive than if we were to give either a more methodical description or more restricted catalogue.

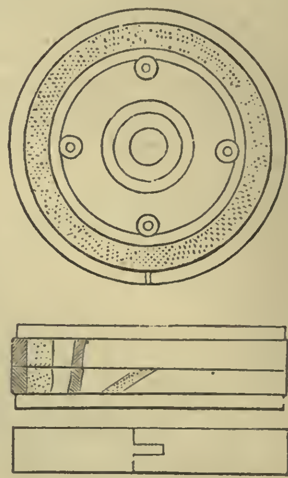
A consideration of the annexed sketches leads us to rank metallic packed pistons under two divisions, (which, if not perfectly distinct, are sufficiently so for the purpose of classification,) to one or other of which each may be referred: those in which the expansive force of the rings alone is used, and those in which it is either assisted or entirely superseded by springs. Of the former kind, we may reckon three varieties; first, those in which hemp packing requires to be compressed into the space between the rings and the piston, to aid the elasticity of the former; this is commonly the case in pumping engines, where hitherto the more complicated and expensive descriptions of packing have not been generally adopted.

Fig. 1535 represents a piston of this variety; the oblique cut in the ring being designed to prevent the sharp edges of the break from grooving the cylinder. In this description of piston, two rings are generally employed, one above the other, with the breaks about 90° apart, to prevent the steam escaping at the joint. This is the simplest kind of metallic packing, but when properly fitted up, it possesses nearly all the advantages of the more complicated descriptions; the only disadvantage being the necessity of occasional adjustment, when the internal hemp gasket loses its elasticity, the frequency of which depends upon the accuracy with which the end joinings of the external rings are contrived to prevent the inlet of steam into the hemp, and also in some degree upon the temperature and pressure

of the steam itself. Another form consists of a single ring with a tongue joint, as shown in the figure.

Closely allied to the above is what we may term the second variety of this species, an external packing ring like the former, but deriving its tightness from its own elasticity, and, of course, not dependent on the hempen packing behind. The simplest and perhaps the most common method of giving the requisite spring is to turn the packing rings a little larger than the diameter of the cylinder, and when sawn through to cut a tenon and mortise, or a half check in the abutting ends, and then to compress the ring by an iron hoop with screws, and to fix it temporarily with a pin put through the overlapping or mortised ends; in this state the rings are ground on the surface joints, and the piston made ready for its place; when, the hoop being unscrewed and the temporary pin withdrawn, the rings are suffered to expand in the cylinder by their own elasticity, which will generally continue to act till the rings and the cylinder are so much worn as to permit the rings to expand to their natural extent.

1535.



Scale.—1 inch=1 foot.

Sometimes the abutting ends are left plain, in which case a piece is merely cut off one end, to allow the ring to be compressed to a lesser diameter. Great diversity of opinion exists as to the merit of this species of packing: that it is a decided improvement upon the former is unquestionable, but it is alleged, that in accuracy of form, and facility of application to the cylinder, it is greatly inferior to the ordinary more complex varieties, with a number of segments and artificial springs to each. It is said, in the first place, that it tends to wear the cylinder off the truth. Appeal to experience might seem the shortest way of settling the question, as many pistons both of the simple and the amended construction are in use, but in this, as in many other cases, recorded experience only serves to prevent any conclusion whatever, or rather tends equally to two contradictory results.

Let us then investigate the action of the simplest form. The ring, when first compressed, does not naturally assume the circular form, as by the two ends being brought together the tendency to expand to its original dimensions is mainly checked in only one direction. When confined in the cylinder, however, it will be seen at once that it is compressed equally in all directions, and must therefore exert a corresponding force equally in every direction, to recover its original dimensions. This appears so plain, as scarcely to be susceptible of illustration.

The variety, ingenuity, and complexity of the various contrivances adopted, to correct this supposed defect in this description of packing, and the alleged success by which they have been attended, must be our apology for dwelling on the subject. But although the apprehended evil did exist in its full amount, and the rings really had a greater tendency to expand in the direction perpendicular to the diameter passing through the break, we do not see what bad effect would ensue; the cylinder would be worn almost imperceptibly oval, till at length the inequality of pressure in the ring would be exactly counterbalanced by corresponding ellipticity in the cylinder; and not only so, but the next rings that happened to be put in would fit with as great truth as the most hair-breadth system of compensation could possibly effect, since the alleged unequal expansion of the ring would then correspond exactly with the shape to which the cylinder has by that time worn.

It is abundantly obvious, however, that the effect upon the cylinder of the unequal expansion might be altogether neutralized, (were it ascertained to have any proper existence,) by using two rings instead of one, the position of the joints being 90° apart. It is not uncommon to have the rings placed with the joints on opposite sides of the cylinder, or 180° apart: an arrangement only useful to prevent the passage of the steam through the single break, (an object which might be easier attained in another way,) and incapable of exerting a correcting influence on the above-named inequality.

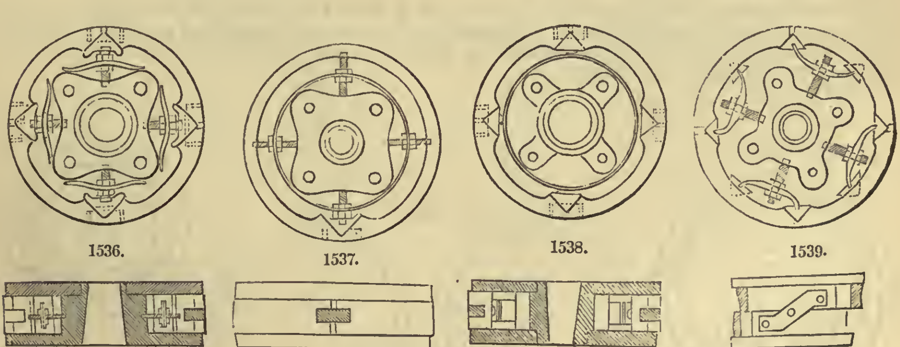
Under the third modification of this description of packing, we class pistons in which each ring is still in one piece, but in which some of the above modes of compensation are had recourse to. The common method is, simply to turn the ring about one-third thinner towards the part where the joining is made; two rings are commonly used, the position of the joints being as above described, and instead of the rings being turned of greater than the required diameter, and then sprung in, the requisite elasticity is given by hammering the thicker semicircumference on the hollow side. Of course, the same method may be taken with rings of uniform thickness, and to derive the full effect of the hammering, it might be well to retain the original skin of the casting on the inside of the ring. The advantage of giving the requisite elasticity by hammering rather than by compressing the ring, lies in the more perfect circularity ensured by the former; but were the precaution taken to turn up the compressed rings in the lathe, this difference would no longer have place; and this is now generally done in addition to the hammering.

This arrangement has been generally found to work very well; but perhaps not better than the preceding more simple variety, when the workmanship of both is equally correct. Numberless methods have been taken to prevent the escape of the steam by the open end joints which this species of ring exposes; frequently hemp packing is put behind the rings; sometimes they are merely cut without any further provision; but by far the best plan, is to rivet a piece of brass or iron, previously fitted to the proper curvature, to the inside of the ring on one side of the break, so that it shall apply correctly to the other side, and slide along steam-tight as the ring expands by wearing. Inattention to this simple precaution has been the occasion of great inconvenience, and has even led to the substitution of a much more expensive, though not in reality much more efficient system.

The second principal division of our subject comprises many subvarieties: we mean that class of pistons where artificial springs are used, acting in most cases by the intervention of blocks or wedges. The most common construction is as follows:—Two strong cast-iron rings of such dimensions as to have no perceptible elasticity themselves, (say from 1¾ inch to 2½ inches square in the cross-section,) are cut, each into from three to six or eight segments, according to the size of cylinder, or other regulating circumstance, placed the one above the other, so as to break bond at each joint, and at each break part of the ring is cut away to admit the introduction of a wedge usually of the angle of 90°, the point of which may be ¾ inch from the surface of cylinder: a common elliptical spring is then introduced between the body of the piston and the back of the wedge. Sometimes, instead of a wedge, a simple block is used, or the spring presses immediately upon the back of the ring.

In the original form of this piston the points of the wedge came in contact with the cylinder, being situated in the periphery of the piston, and, in order to prevent their injurious action in grooving the cylinder, it was proposed to make them of softer metal. In this description of piston, the mode of action of the wedges is what seems principally to require investigation. When the points of the wedges are not in contact with the cylinder, the mode of action is sufficiently obvious; the intervention of the wedge serving simply to multiply the energy of the springs on the principle of the wedge, as a simple mechanical power. Of course, the more acute the angle of the wedge, the greater force is imparted to the springs, on the principle of virtual velocities; and were the segments only required to expand indefinitely, instead of expanding and contracting by turns, to suit the inequalities in the cylinder, then a very acute wedge might be used; but as the wedge must be ready to spring back, to allow the packing to yield when it comes to a tight part of the cylinder, as at the top and bottom of the stroke, it is plain that the inclination must be considerably greater than the angle of repose; it is seldom, however, made less than 80° or 90°, but we believe a considerably sharper angle would be found to answer. Considering now, for a moment, the case in which the points of the wedges come in contact with the cylinder, it might seem, at first sight, that they would exert no pressure at all upon the adjacent segments; and such would be the case, were it possible for them to wear no faster than the rings themselves; a little consideration, however, will show that this can never be the case, as the wear upon the wedge must be to that of the ring, in the proportion of the side to half the base of the wedge; that is, in the case of a right-angled wedge, as the diagonal to one of the sides of a square: were the wedge and cylinder then to be made of the same material, the wear of the cylinder opposite the wedge would exceed that of the rest of its surface in the above proportion, or probably in a somewhat higher ratio, arising from the different grain of the metal composing the wedge. The wedges, however, are almost always made of gun-metal, which serves in a great measure to neutralize what would be otherwise the injurious tendency of this arrangement.

Fig. 1536 represents two views of the locomotive piston. The peculiarity of construction and mode of action is apparent from inspecting the drawing. By fitting a tongue-piece, or tenon, into a corresponding mortise, in both wedge and ring, it is intended to prevent the passage of steam at the breaks of the segment, instead of the common method of using two rings, each of half the thickness, with the joinings of the one ring placed midway between those of the other. We believe this construction has been found to answer perfectly; but this is not paying it a distinguishing compliment, as we shall soon see that the same may be said of certain other descriptions, about which there is not above one-fourth of the workmanship here displayed.



SCALE.—1 inch=1 foot.

Fig. 1537 represents plan and section of a piston, differing from the above in having only one wedge and break in the ring instead of four. The set screw, on the side farthest from the wedge, might be omitted; the two side-screws serve in some measure to compensate for the sluggish action of the right-angled wedge, which seems rather to press the ring against the cylinder at the point immediately adjacent than to force it open, and thus make it bear equally all round. A more acute wedge would propagate the pressure of the spring more readily throughout the entire circumference. A circular spring, like that used here, while it possesses several conveniences, is yet less delicate and perfect in its action than the common elliptical kind; and perhaps, too, less easily reset or retempered.

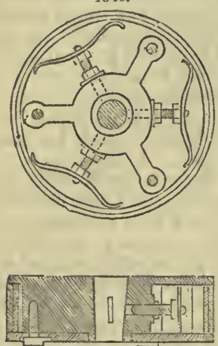
Very similar to the first variety is that shown in Fig. 1538. We doubt whether the slight superiority in point of simplicity gained by doing away with the adjusting screws, and substituting a single spring hoop, be not more than counterbalanced by less perfect action. A method intermediate between the

wo last is sometimes adopted; the packing-ring is cut, and a sliding piece and wedge employed in two pposite places, and a circular spring, with set screws, acts upon each.

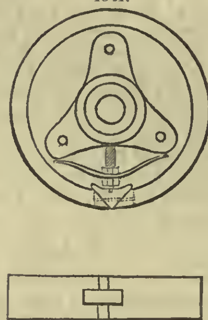
Fig. 1539 represents a plan of the piston. The distinctive feature in it is, that each spring acts upon ne wedge in the upper ring, and another in the lower, the centre of the spring, contrary to common usage, being made the "point d'appui," from the body of the piston.

Fig. 1540 represents a piston that has been much used. It consists of three concentric rings, the two outer being rebated and mortised upon their edges, and together filling up the space between the flanges of the piston. The inner ring is equal in depth to the two outside rings. When the rings are turned to fit the cylinder and each other, they are hammered on the inside, to give them a tendency to spring outwards, and are then cut through, to allow them to expand. The divisions of the rings are placed so as to break joint. To provide for the wear of the outside rings, springs are placed at the back, which can be tightened up by means of screws bearing upon the centre part of the springs.

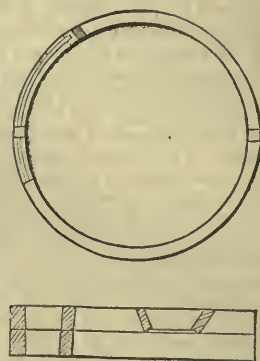
1540.



1541.



1542.



SCALE.—1 inch=1 foot.

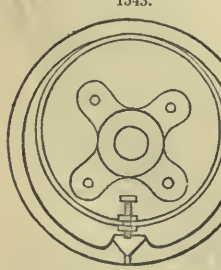
Fig. 1541 represents a kind of piston very similar to Fig. 1537. The pistons are sometimes made of brass. This is an advantage in horizontal or inclined cylinders, as the softness of the material, and the greater lightness of the piston, considerably reduce the wear of the cylinder. Brass pistons have been, on this account, much used for locomotive engines; one drawback, however, to their employment, is, the inferior elasticity of the metal, which renders the employment of artificial springs necessary.

Fig. 1542 represents the packing-rings. The peculiarity of this piston consists in the two rings being grooved and tongued into each other in a manner similar to common flooring-deals.

Fig. 1543 represents the plan of a piston which is superior in simplicity, and at least equal in efficiency, to several of those we have figured.

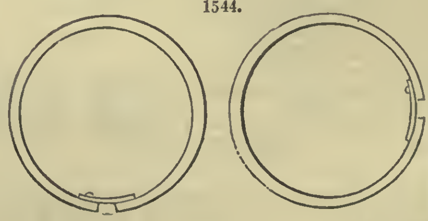
Fig. 1544 represents the piston which is free from all or most of the defects we have pointed out, and has given much satisfaction in practice. The position of the rings, in being placed with the breaks, 90° apart instead of 180°, is one of those trivial but judicious arrangements which often determines the character of a mechanical contrivance.

1543.

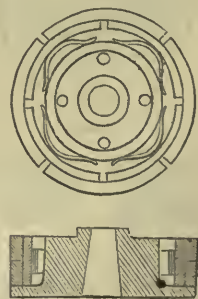


SCALE.—½ inch=1 foot.

1544.



1545.



SCALE.—1 inch=1 foot.

Fig. 1545 is a plan and section of piston much used. It has two packing-rings, ¾ inch × 1¾ inches, each in three segments, pressed out by three elliptical springs with set screws, through the medium of an inner ring equal in depth to the two, and cut in three places.

These then are the principal specimens of locomotive pistons: we shall next describe some of the most approved pistons for marine engines, all of which are also applicable to land engines.

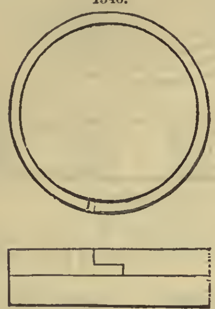
Fig. 1546 represents a variety of packing adapted for marine engines.

Fig. 1547 represents Jessop's spiral metallic packing. On considering the action of the spiral coils, when the ring is compressed into a lesser diameter, it will be found that the tension of the springs is a

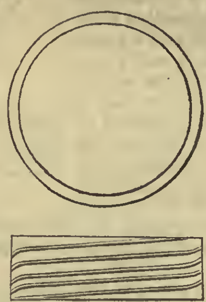
minimum at the centre of the coil; while it increases towards each extremity in the ratio of half the number of coils to unity.

Fig. 1548 represents an arrangement that was formerly extensively adopted. The packing consists of four rings, from $\frac{3}{4}$ to $1\frac{1}{4}$ square, according to the size of the cylinder, which may vary from 6 to 50 inches in diameter. In pistons of the latter dimensions the rings are turned fully two inches more in diameter, and afterwards cut in one place, and bent to the proper circle in a mould prepared for the purpose—the ends being half checked in such a way as to be steam-tight without the necessity of using packing behind, which, however, is frequently added. In order to bring the cylindrical surface of the rings sooner to an exact bearing, a groove is turned out of the outer circumference of each: this may help, besides, to keep the piston tight, by affording a lodgment for oil and tallow, and may in certain circumstances be of considerable use. In one instance within our knowledge this kind of piston has been at work, with occasional interruption, but little or no repair, for a period of ten years.

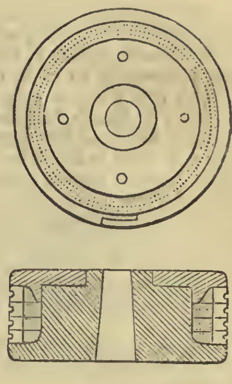
1546.



1547.



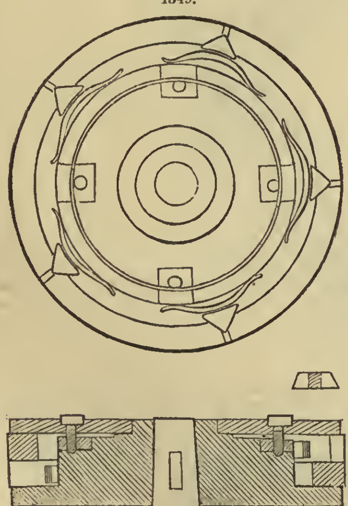
1548.



SCALE.—1 inch=1 foot.

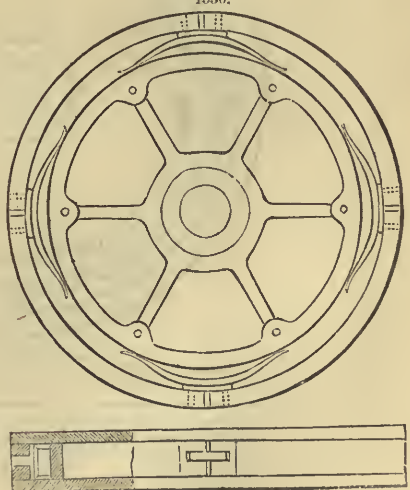
Fig. 1549 represents plan and section of piston both for marine and land. This may be regarded as a favorable, and at the same time, characteristic specimen of the most generally approved and widely adopted variety of packing in which separate springs are employed. The ease with which the springs may be bent and reset to the proper compass prevents set screws from being required: the only seriously objectionable point seems to be the expense of fitting and grinding steam-tight the ten wedges required. The use of wrought-iron nuts, fitted into the body of the piston to receive the junk ring screws, instead of tapping them into the cast-iron, is a very obvious improvement.

1549.



SCALE.—1 inch=1 foot.

1550.



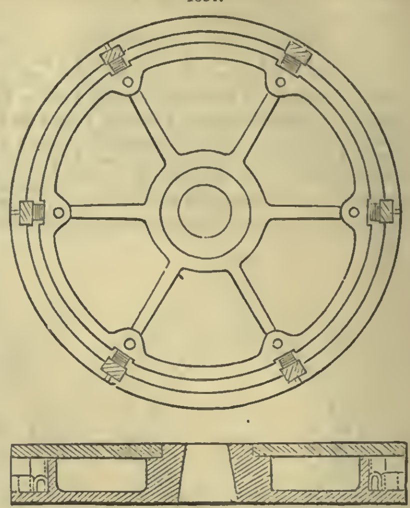
SCALE.—$\frac{1}{2}$ inch=1 foot.

Fig. 1550 represents a form of marine piston. To enter into a detailed analysis of it would be superfluous, after having considered so much at length the general principles by which our judgment has been regulated.

Fig. 1551 is another form of piston. The peculiar shape of the blocks against which the springs press, instead of the usual V wedge, is one point of identity.

Fig. 1552 represents the form of piston much used. Two rings, about 2¼ inches square, (cylinder being 65 inches diameter,) divided into two segments, the lengths of which may be in the proportion of 1 to 5, each ring being pressed out with a number of springs, generally made very stiff, and of little compass: the rings, in consequence, wear so rapidly, that we have known them to require to be eked with a considerable thickness of copper at the ends. The distinguishing feature of this piston lies in the cut on the outer circumference of the rings being made at a considerable angle with the perpendicular, while that on the inner side is vertical; an arrangement that we do not recollect to have met with before.

1551.

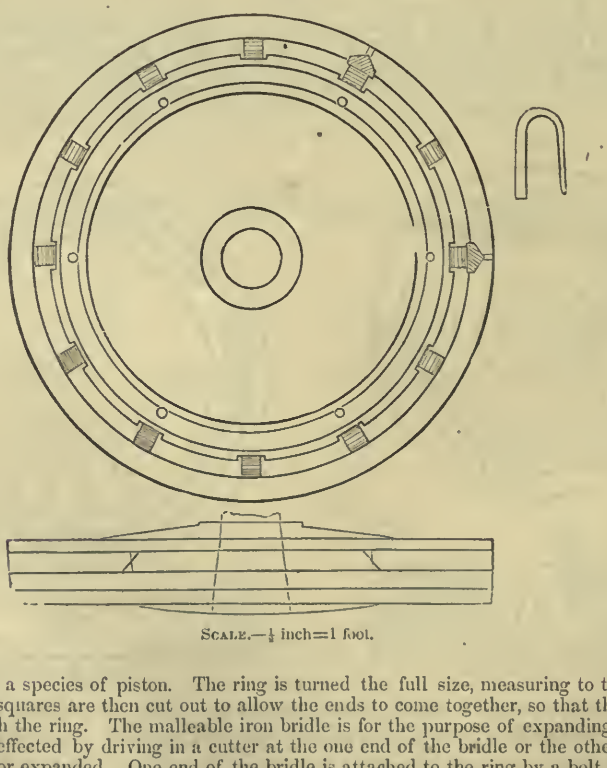


Scale.½— inch=1 foot.

Fig. 1553 represents a species of packing-ring also much employed. Only one packing-ring is used, about 3¾ inch × 1¾ inch; sprung in from a larger diameter, or hammered internally so as to have considerable elasticity. This ring is cut in only one place, and a piece, 8 or 9 inches in length, half the thickness, and about one-third the depth of the ring, is checked in on the upper side, in order to break bond; and at the back of the joint a block is placed, screwed to the one end of the ring and loose at the other, so as to prevent the steam from passing through the cut. In addition to the elasticity of the ring, it is pressed out by six elliptical springs. This is, on the whole, one of the best marine pistons. The ring, however, in wearing, deranges the joint between the ring and the small segment-piece. The joint opens at each end, so that the only contact comes to be at the central point, which is a defect.

Fig. 1554 shows plan and section of the piston of a cylinder 68 inches diameter. There are two rings cut into two segments, the lesser being one-third the circumference, with V blocks at the joinings, and stiff elliptical springs.

1552.



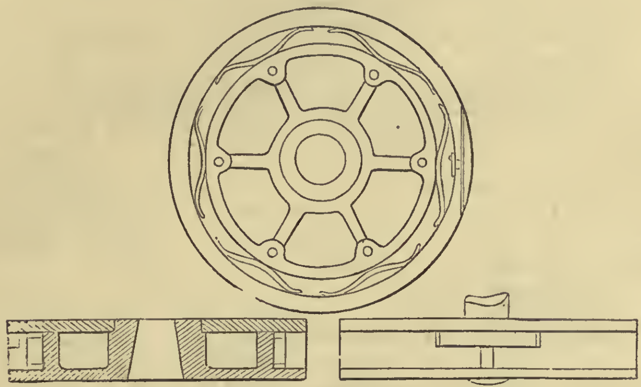
Scale.—½ inch=1 foot.

Fig. 1555 shows a species of piston. The ring is turned the full size, measuring to the point of the tongue-piece, and squares are then cut out to allow the ends to come together, so that the tongue-piece is in one piece with the ring. The malleable iron bridle is for the purpose of expanding or contracting the ring, which is effected by driving in a cutter at the one end of the bridle or the other, whereby the ring is contracted or expanded. One end of the bridle is attached to the ring by a bolt, which slides in an oblong hole in the bridle; and if a cutter be driven between the bridle and one end of the piece

ground on the back of the joint, the ring will be expanded; whereas, if driven at the opposite side, the ring will be drawn together.

Fig. 1556 represents a marine engine piston. The tongue-piece is not cast in one with the ring, but is put in with pins; and the slot is on the incline, to prevent a rut in the cylinder. The tongue-pieces, of this and the preceding variety, are of course ground in, a piece being ground on the back to prevent the steam from passing. This species of piston ring is probably among the best yet introduced in practice. It is a very common fault of metallic pistons that the springs are made too weak. We have often known them to be too weak, but never in any one instance knew them to be too strong.

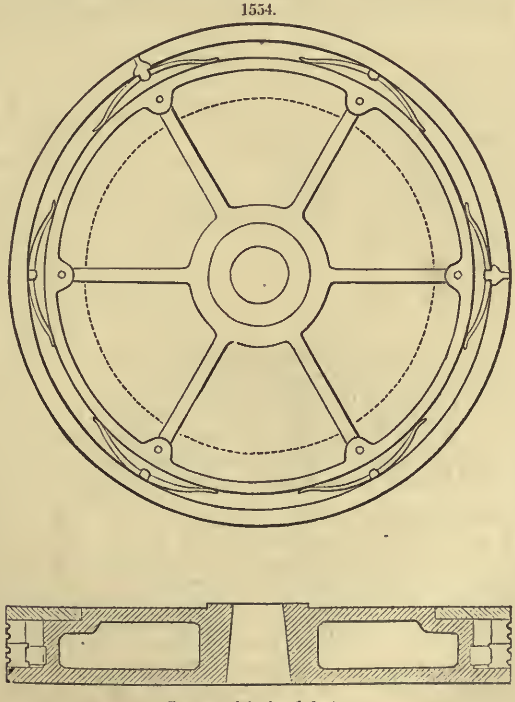
1553.



Scale.—½ inch=1 foot.

Fig 1557 represents the piston often used for cylindrical slide-valves. By raising or lowering the screw, it will be evident that the rings are compressed or expanded. A flat place is of course cast in the body of the piston to leave room for the bridle.

1554.

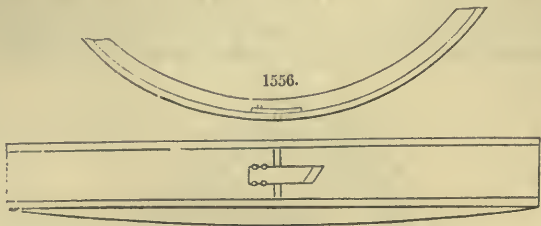


Scale.—½ inch=1 foot.

In the pistons of oscillating engines, it is necessary to take precautions against any compression of the packing-ring by the weight of the piston during the inclination of the cylinder. The method pursued by Messrs. Penn is to pack the space between the metallic ring and the piston with hemp. It might be a good way to force out the ring by means of a V block placed on one side of the piston, in the line of the

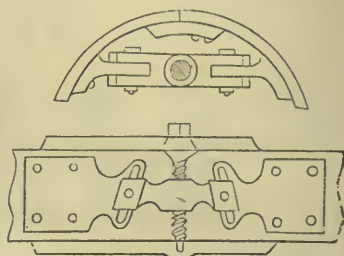
trunnion, a steady pin being inserted in the piston on the opposite side, with a corresponding oblong hole in the packing-ring, so as to prevent the packing-ring from turning round at the same time that it was permitted to expand. Messrs. Penn make use of a single ring and tongue-piece with the block behind recessed, so as not to interfere with the hemp packing. The upper side of the ring, too, is sharpened off to an edge.

1556.

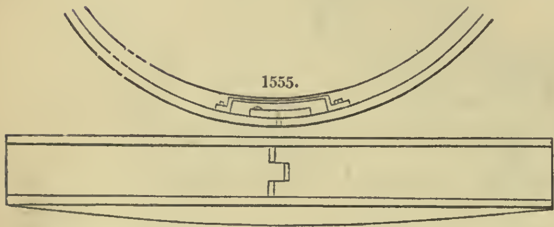


SCALE.—$\frac{1}{4}$ inch=1 foot.

1557.



1555.

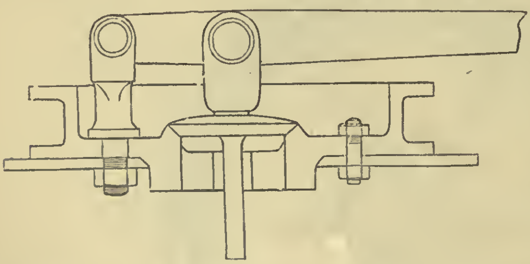


SCALE.—$\frac{1}{2}$ inch=1 foot.

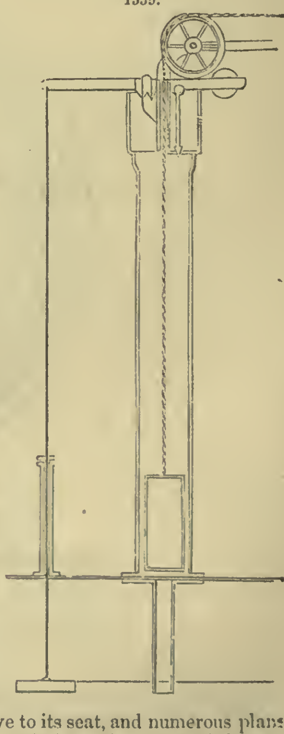
SCALE.—1 inch=1 foot.

Valves.—The function of a valve is to open or close a passage, and all the varieties are divisible into the genera of lifting and sliding valves. Sliding-valves are generally employed to admit the steam alternately above and below the pistons of engines, except in the case of pumping engines, and there

1558.



1559.



lifting or spindle valves are usually employed. Safety-valves are always spindle-valves, though a slide-valve, opened by the rise of a column of water or mercury, has been proposed as a safety-valve. The valves of pumps are generally spindle, flap, or ball valves, but are slide-valves sometimes. A cock is to be regarded as a circular sliding-valve. The diameter of the spindle of spindle-valves is usually made about one-eighth of the diameter of the valves; in small valves the proportion is greater.

Safety-valves.—A common proportion is a circular inch of orifice per $1\frac{1}{4}$-horse power, or ·8 of a circular inch per horse power. In marine engines safety-valves are usually lifted by a lever, which presses up the spindle from underneath, and the weights are either wholly or partially hung from the spindle. The spindles are sometimes guided by means of an iron bar, which passes across the steam-chest; but this is not a commendable practice, as explosions have occurred from the jamming of the spindles in the guide, in consequence of an alteration of shape in the steam-chest when the pressure came on.

Fig. 1558 represents the safety-valve of a locomotive engine, which is of the steelyard kind, and the end of the lever is kept down by a spring.

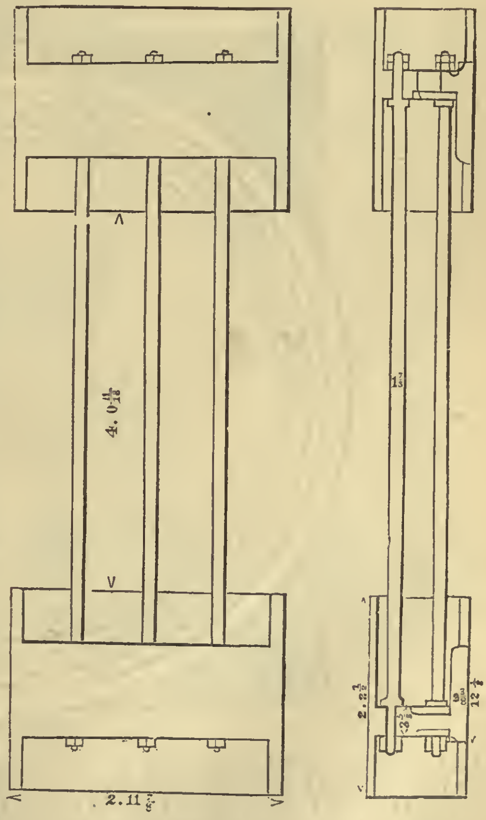
Boiler explosions sometimes arise from the adhesion of the safety-valve to its seat, and numerous plans have been devised, and some of them of considerable ingenuity, for obviating this source of danger.

The ordinary method of feeding land boilers by a head of water may rank among these contrivances: it is shown in Fig. 1559. A float, which is usually made of stone or iron, is so balanced, by means of a counterweight, that it rises or falls with the fluctuations of the water level, and in so doing opens or closes a valve in a small cistern, at the top of a stand-pipe set on top of the boiler, thereby maintaining the water at the right level. The stand-pipe is of sufficient diameter to receive a float connected with a chain proceeding to the damper; and as the water is forced up in the stand-pipe to a height corresponding to the elasticity of the steam, the float in the stand-pipe will rise and fall with the varying pressure, thereby adjusting the vehemence of the draught to the wants of the engine. If the pressure becomes very high, the water will be forced out of the boiler through the feeding-valve. This valve, however, is usually made too small to be capable of answering as a safety-valve, but it gives intimation of danger. In steam vessels an upright pipe has been recommended to be applied to the top of the boiler, of sufficient capacity to give free exit to the steam, and descending beneath the water level, so as to be under ordinary circumstances filled with water. When the steam becomes too high, the water is forced up this pipe, and proceeds into the chimney by a branch-pipe provided for the purpose. If the pressure be not speedily relieved, the whole of the water above the mouth of the pipe will leave the boiler, and then the steam will rush out. Another plan consists in the application of a vessel at the end of a lever, to receive the water which flows over from the upright pipe, and this vessel of water is so arranged that its weight opens the safety-valve. In some combinations a column of quicksilver is employed, instead of a column of water; but it has been found that the quicksilver is gradually dissipated by the action of the steam. A large steam-gage is recommended by some persons as an effectual safeguard against explosion, in the event of an adhesion of the safety-valve; but for all ordinary pressures we think the column of water will be found to be a preferable expedient.

1560.

Slide-valves.—There are three principal varieties of slide-valves—the long D, the short D, and the three ported. This last valve, Fig. 1560, consists of a box set over a central port, and moved alternately over ports set on each side of the central port, so as to establish a communication between the central and side ports alternately. The central port is the escape port: the steam passes in the direction of the arrows, and when exhaustion is being performed by one port, steam is being admitted by the other. This species of valve is used very extensively in high-pressure engines, and almost universally in locomotives. It is very simple; and by leaving the face of the cylinder when the pressure within the cylinder exceeds the pressure in the valve-casing, it enables the water to escape when the engine primes: but it occasions a considerable waste of steam if the ports and passages are large; and if they are not large, a considerable loss of power arises from the extra-resistance experienced by the piston.

1561.



The long D valve has always been in much favor with engineers, though, as we think, without sufficient reason. The short D valve is, in our judgment, preferable, and we give in Fig. 1561, an excellent specimen of this species of valve. Some short D valves have only one rod to connect the ends, and others have two; but three are preferable, as they give greater stiffness than is otherwise attainable. It is expedient to zinc the connecting-rods, as in the wake of the ports they frequently get wasted rapidly away by the steam.

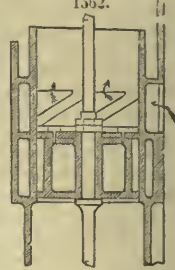
The piston-valve with skewed ports is represented in Fig. 1562. This species of valve is, in our judgment, preferable to the D in many respects. It is more easily worked, admits of metallic packing, and is not liable to have its form altered by twisting.

In working large engines considerable difficulty is experienced in handling the valves, from the weight and the pressure of the steam forcing the valve against the face of the cylinder. Various schemes have been adopted to obviate this disadvantage. In some cases a small engine has been used to work the valves at starting, and another plan has been to balance the valves by the opposing pressure of the steam. One of these balance valves is represented in Figs. 1563, 1564, and 1565. It is a slide-valve, and has no hemp packing as is usual, but is kept tight by means of a metallic packing-ring, divided into segments which are pressed against the inner side of the valve-chest back by spiral springs

and steam pressure. Some inconvenience might be anticipated from the circumstance of the rubbing surface of the packing-ring at the sides of the valve being greater than at the ends.

a a a is a brass ring divided into segments, as shown in the plan, the object being to allow the ring to accommodate itself to any slight curve that may be caused by the pressure of steam on the valve-box back or cover. *b b b b* is a space containing about three layers of well-plaited square gasket. *c c c c* is a brass ring in one piece fitted loosely into the groove, having on one side of it a number of small steel pegs, *d d d d*, on which is placed spiral springs. These springs force the ring, and by it the hemp packing is pressed hard against the brass segments, causing them to slide steam-tight against the valve-box cover, the pressure being further regulated by a communication made between the space in which the spiral springs work, and the steam in the valve-box.

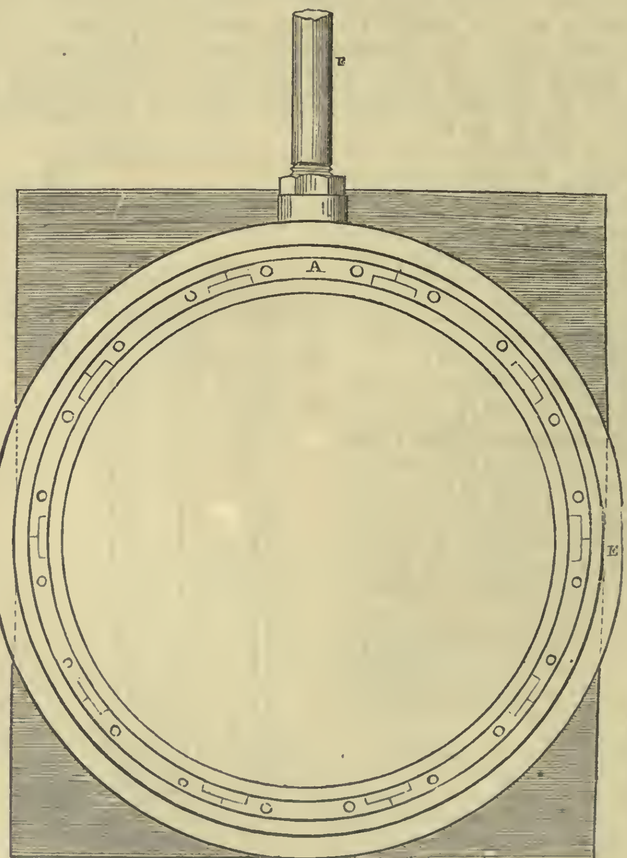
1562.



A communication is made between the condenser and the space within the brass ring *a a a* in the valve-box cover, and the condenser regulated by a cock, so that when the engineer is handling the engine he can cause a vacuum at the back of the slides. E E E is a wrought-iron hoop bound to fit the turned part of the valve, which slides freely in it, uninfluenced by the valve-rod F F.

The valve employed by Messrs. Penn in the most recent of their oscillating-engines, is substantially the same with that just represented. The ring, however, is in a single piece, and is tightened against the back plate by means of another ring, armed with four lugs, lying beneath the packing-ring. Between this ring and the packing-ring hemp packing is interposed, and the lower ring is raised up by unscrewing, out of bosses on the valve, four bolts passing through the lugs. These bolts may be unscrewed, and the packing tightened, by removing four plugs in the back of the valve-casing. By this method of arrangement

1563.



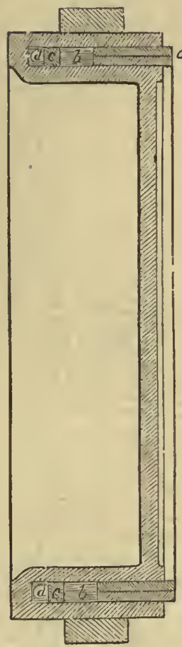
Back View.

it is not necessary to make the back of the casing removable, but merely to plane and fit the back to the rings before the parts are put together. The back plate which forms the cover of the casing is scraped as carefully as the valve and cylinder faces, but only as much of the back plate is thus fitted as the ring comes into contact with during the travel of the slide, and the fitted portion is cast a little higher than the other portions.

Expansion-valves.—Slide-valves are the most satisfactory species of expansion-valve; but spindle-valves are the simplest, and they are the most frequently employed. Most of the spindle expansion-valves are of the double beat or equilibrium kind, such as are used in the Cornish engines. The form of the cam is a sort of twisted elliptical cylinder, so to speak, against the exterior surface of which a pulley fixed, on the end of a lever, presses, and by the motion thus derived opens the valve.

Fig. 1566 represents the variable expansion-geer of Gonzenbach. It consists of an ordinary short slide-valve and casing, with ports in the back, upon which another slide-valve and casing are imposed. The ordinary valve is worked in the usual manner; but

1564.

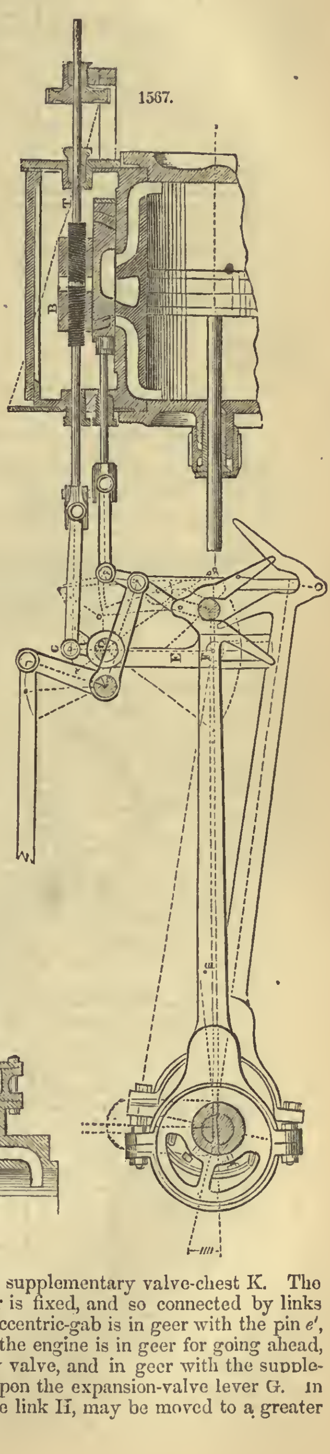


Transverse section.

1565.

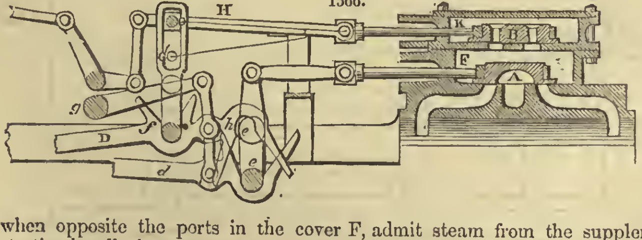
Perpendicular section.

1567.



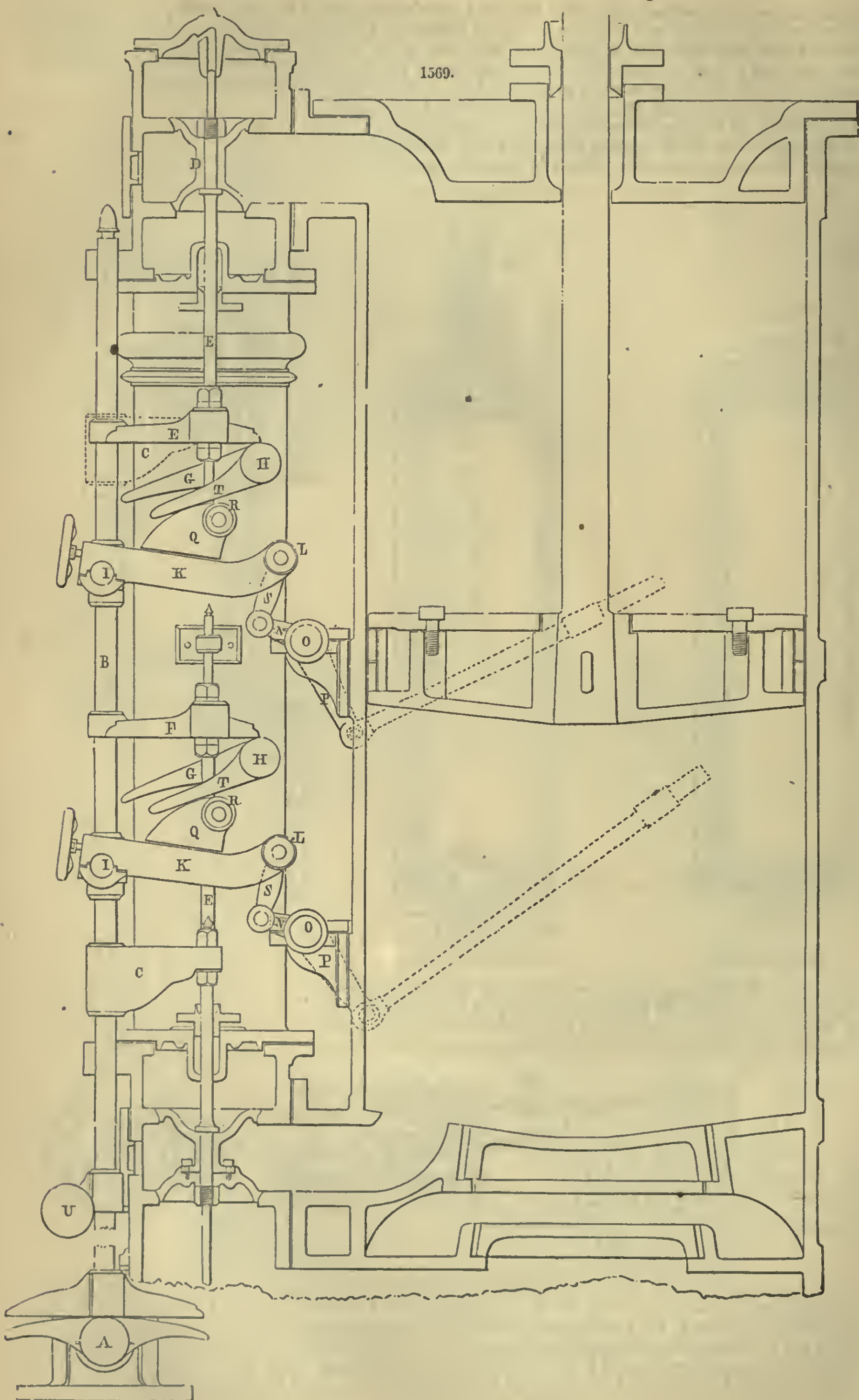
the travel of the supplementary valve may be lengthened or shortened, so as to cut off the steam at any part of the stroke. A is the common valve, and F the valve-chest; B is the supplementary valve, which is a solid block with two perforations, which,

1566.



when opposite the ports in the cover F, admit steam from the supplementary valve-chest K. The starting-handle is connected with the shaft *g*, upon which a lever is fixed, and so connected by links with the extremities of the eccentric-rods D and *d*, that when one eccentric-gab is in geer with the pin *e'*, upon the valve-lever, the other shall be disengaged. In the figure the engine is in geer for going ahead, and the reversing eccentric-rod D is disengaged from the ordinary valve, and in geer with the supplementary valve, by means of a second gab *f*, which receives a pin upon the expansion-valve lever G. In this lever there is a long slot, in which a pin G, fixed on the valve link H, may be moved to a greater

1569.

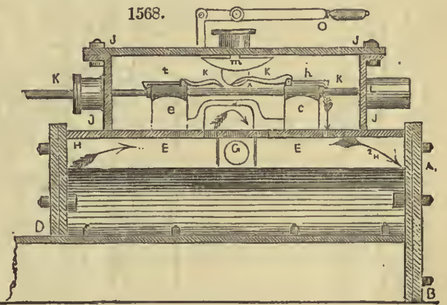


or less distance from the centre of the expansion-valve shaft, by means of the handle T; and the effective length of the valve-lever being thus varied, the travel of the valve receives a corresponding variation. The expansion-valve thus receives the reversing motion while the slide-valve is receiving the forward motion.

Fig. 1567 represents the variable expansion geer of Mayer. It consists of an ordinary valve, with the addition of perforations through the top and bottom faces, each of which is covered by a supplementary valve upon the back of the first, consisting of two solid blocks, into which a valve-rod is screwed, having a right-handed screw where it penetrates the one block, and a left-handed screw where it penetrates the other; so that the blocks will be set closer or further apart, according to the direction in which the rod is turned. The ordinary valve receives its motion in the usual way, and the expansion-valve is moved by means of a pin attached to the piston-rod, which works in a slotted lever, to which the expansion valve-rod is attached. The motion of the two valves is, therefore, at right angles, and the expansion-valve is about one-fourth of a revolution in advance of the steam-valve. In Fig. 1567, A is the steam-valve, B B the expansion-valve, T T the valve-rod, with right and left handed screw; G a wheel attached to the valve-rod, over which a pitch chain passes, by means of which the valve-rod is turned, and the blocks are altered so as to give the requisite amount of expansion; D is the valve-shaft, and C E the valve-lever; F is the pin attached to the piston-rod. In all cases in which the motion of the expansion-valve is the same as that of the piston, the slide-valve must be provided with lap.

Sliding cut-off valve.—This is the invention of Mr. Simon P. Winne, of Albany, N. Y. Fig. 1568 is a vertical longitudinal section of the steam chest and passages of a cylinder, with the valves in their place and ready to act. A B C D represent a steam cylinder, having on its top A C, the usual hollow steam channel E E, divided by partitions to separate the entering from the issuing steam in the usual way with the exit passage G, and openings into the cylinder at H H. J J J J is a steam chest made a little longer than the ordinary kind, but of the same form. The steam entering in by the passage X, fills the chest, from which, as will be noticed, there are four openings into the channels E E, and one into the exit passage G. They are all properly faced with slides, and arranged in reference to the valves to move over them, as seen in the engraving. *c d e* are the three slide-valves. *c* and *e* have solid bottom surfaces, and *d*, the central valve, has the usual chambered passage to effect a communication together between two of the three central passages from the chest into the steam channel. The valve-rod K passes through a stuffing-box at the one end, and has the other end passed through a stuffing-box or into a chamber L, bored out to receive support and steady its movements. The rod passes through the upper parts of the valves *c e*, which are pierced to receive it; but it is not attached, but moves freely through them. The rod K, moved by the eccentric, communicates motion to the valves by means of two stop-nuts, which screw upon a thread in the rod for adjusting the cut-off. These nuts will readily be noticed at the ends of the catches.

1568.



Upon the two valves *c* and *e* are mounted catches *h* and *i*, moving on pivots, and have handles *k k*. The catch drops down upon the valve-rod and is held in this position by its own weight or a spring, as may be found most suitable. *m* is a metallic plate placed over the centre of the valve range. It has its lower edge curved or made flat, as may be desired. Its chord is parallel with the rod K. This plate is attached to a spindle at right angles to it, which passes through a stuffing-box, where it is attached to the handle O, for raising and depressing it, thus attaching and detaching the catches *h* and *i* from the nuts on the rod K. The valve *d* lies upon its bed unattached to the rod, and is only moved by the impulse of *c* and *e* alternately. Between these two valves and *d* there is a space to be determined by the portion of the stroke of the piston at which the steam is to be cut off.

Operation.—The valves are to be attached to the rod by the catches when the cut-off is to be used. The engine in the engraving is represented as having just begun the stroke of its piston from left to right, and the valve-rod from right to left. Before the piston has passed over one-third of its stroke, *e* will have covered the first opening, cutting off all passage of steam from the chest to the opening H of the cylinder, and will keep it covered during the remainder of the stroke, during which, valve *d* is kept stationary, passing steam from the right passage of the cylinder H, through the two passages indicated by the middle arrow, and out of G, until the valve *e* impels it to the left, and the valve *c* is carried over the other opening, and opening the other exit passage. This completes the stroke, and the same operations are repeated continuously from left to right and right to left. When it is desired to give the engine full steam, the lever O is depressed, by which the catches are raised to allow the three valves to act in concert, operating as a single slide driven by a cam. The stroke can be cut off and regulated by the handle O. It is only necessary to depress the bar-plate *m*, to permit the proper catch to drop over the stop nuts, and the required cut-off will be effected. The valves when used for upright engines may be kept in their places by springs during the absence of steam pressure.

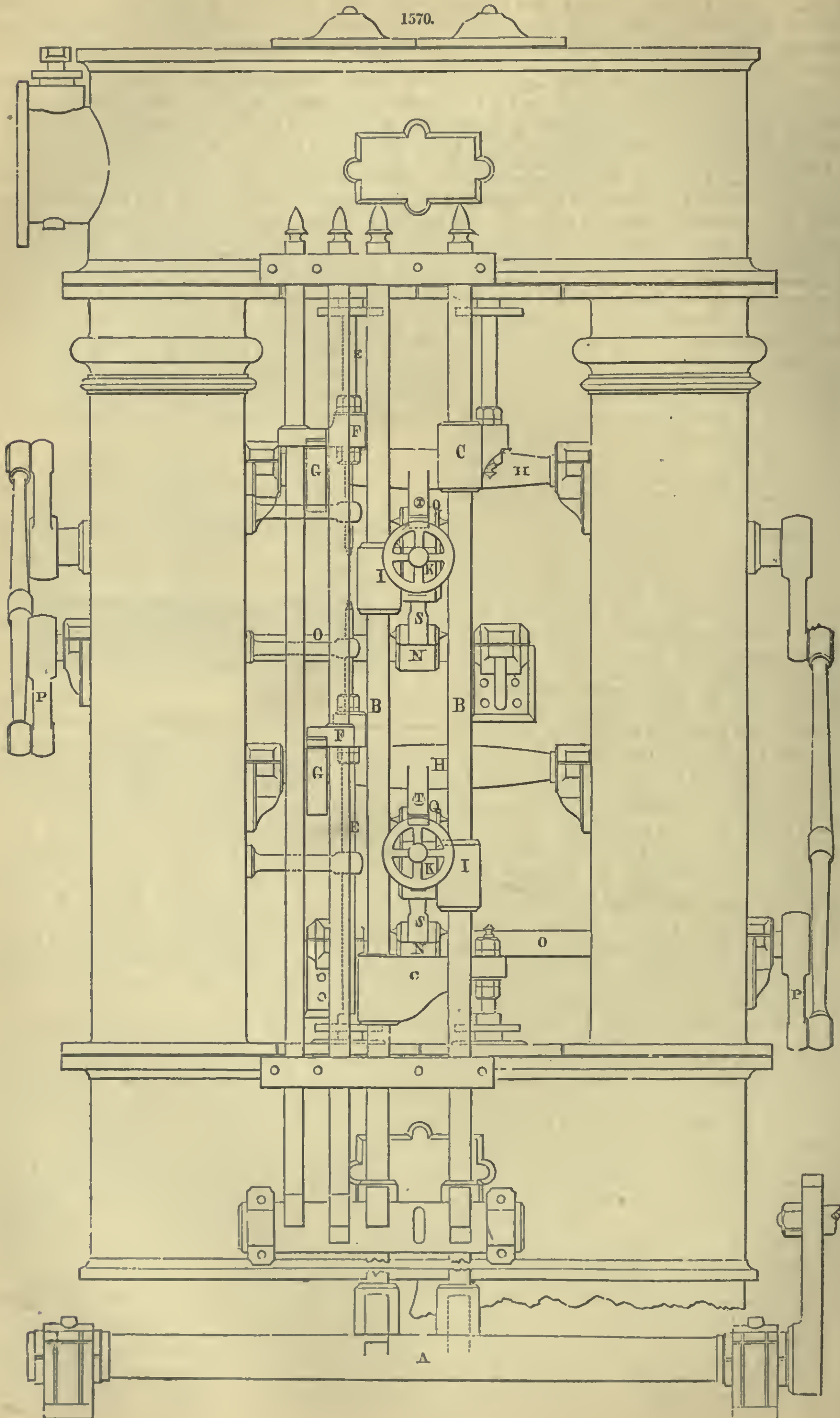
Expansion—Allen's cut-off.—The combination whereby an adjustable cut-off is obtained for engines using poppet-valves, is represented by the drawings hereto attached, Figs. 1569, 1570.

A is the rock-shaft, B the lifting rods, and C the exhaust-valve lifter, as usually arranged and worked.

D is the steam-valve. E the valve stems. F is a piece attached to the valve stem by means of which it rests on the toe G. This toe G is attached to the shaft H. On the same shaft H is the toe T

On the lifting rod B is fastened the stud I, having a centre on which it is supported, and turns one end of the lever K; the other end L is connected with the arm N, by the rod S. This arm N is at-

1570.



tached to the shaft O. On the same shaft O is attached the arm P, to which arm is given a reciprocating motion coincident with that of the piston, and taken from the beam or any part having the same motion (suitably reduced) as that of the piston.—On the lever K is placed the movable piece Q, the roller R is attached to the piece Q, and on the roller R rests the toe T.

It will be seen that by the *upward* motion of the lifting rod, the end I of the lever K is raised, while by the *downward* motion of the arm N the other end of the lever K is lowered. But it will also be perceived that the upward motion of the end I is at its *greatest* velocity at the beginning of the stroke, while the arm N, which lowers the end L, has no motion at the immediate beginning of the stroke; by reason of these relative motions, the lifting end will have the advantage, and the valve will therefore be raised at the early part of the stroke, but the motion of the lifting end is rapidly diminishing, while that of the lowering end is increasing; it therefore will soon happen that the lowering end will lower the valve more rapidly than it is raised at the other end, and thus the valve will be restored to its seat. The point of stroke *at which* the valve will be restored to its seat, will depend on the proportion of parts, and with suitable proportion parts, on the position of the movable piece Q. If, in the position represented in the drawings, the valve is restored at half stroke, then by moving the piece Q towards the lifting end the valve will be restored at a later point, and by moving it towards the lower end the valve will be closed at an earlier point.—Further descriptions of American engines will be found under the heads, LOCOMOTIVE, MARINE, STATIONARY, and SCREW PROPELLER.

ENGINES, *Summary of*.—The greater part of this summary is taken from the Engineers' and Mechanics' Pocket-Book, by C. H. Haswell, engineer in chief of the U. S. Navy.

Names of Parts.	Nominal Horse-Power of Engine.													
	10	15	20	25	30	40	50	60	70	80	90	100	110	120
Diameter of	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Cylinder	20	24	27	29½	32	36½	40	43	46	48	50	52½	55½	57
Piston-rod	2	2⅜	2¾	3	3¼	3½	4	4¼	4½	4¾	4⅞	5	5¼	5½
Air-pump	12	15	17	17½	18½	21	23	24	26	27½	28	30	31½	34
Air-pump rod	1¼	1¾	2	2⅛	2¼	2½	2¾	2⅞	3	3¼	3½	3¾	4	4¼
Injection-cock	1¼	1½	1⅝	1¾	2	2¼	2½	2¾	3	3⅛	3¼	3¼	3⅜	3½
Hot-water pump	2¼	2½	3	3¼	3½	4	4¼	4½	5	5½	6	6½	7	7½
Feed-pipe	1½	1¾	2	2⅛	2¼	2½	2½	2¾	3	3¼	3¼	3½	3½	4
Steam-pipe	4	5	5¾	6	6½	7	7¾	8½	9¼	10	10½	11	11½	12
Waste water-pipe	5	6	7	7½	8	9	9½	10	10½	11½	12¼	13	13½	14
Beam gudgeon	3½	4¼	5	5¼	5½	6	6½	7	7½	8	8½	9	9½	9¾
Pins in beam ends	2	2⅜	2¾	3	3¼	3½	4	4¼	4½	4½	5	5¼	5¼	5½
Air-pump pins in beam	1¼	1⅝	1¾	1⅞	2	2¼	2½	2½	2⅞	2⅞	3	3⅛	3⅛	3¼
Crank pin	2½	3	3½	3¾	4	4½	5	5½	6	6½	7	7⅜	7¾	8
Main shaft	4¼	5½	6¼	6¾	7	7½	8½	9¼	10	10¼	10½	11½	12	12½
Paddle wheels, in feet	9	11	11	12	13	13	15	17	17	19	19	21	21	23
Weigh-shaft bearings	2	2¼	2½	2½	2⅝	2¾	2¾	2¾	3	3¼	3¼	3½	3¾	3¾
Stroke of piston	24	30	30	33	36	36	42	48	52	56	60	63	66	72
" air-pump bucket	12	15	15	16½	18	18	21	24	26	28	30	31½	33	36
" feed-pump plunger	6	7½	7½	8	9	9	10½	12	13	14	15	16	16½	18
Cylinder cross-head,														
Depth of boss	6	7½	8	9	9½	10½	12	13	14	14½	15	16	17	17½
Diameter of boss	4	4½	5	5½	6	6¾	7½	8	8¾	9	9½	10	11	12
Depth of middle	5	5½	6¼	7	7½	8½	9½	10¼	11½	11¾	12½	13	13½	14
Thickness	1½	1⅝	1¾	2	2¼	2½	2¾	3	3¼	3½	3½	3¾	4	4⅛
Air-pump cross-head,														
Depth of boss	4½	5	5½	6½	6¾	8	9	10	10½	10¾	11	11½	12	12½
Diameter of boss	2¾	3⅜	3½	4	4⅛	4⅝	5⅛	5¼	5¾	6	6½	6¾	7¼	7½
Depth of middle	3½	4	4½	5	5¼	6¼	7	7⅝	8	8¼	8½	9	9¼	9½
Thickness	1	1⅛	1¼	1⅜	1½	1¾	2	2⅛	2¼	2¼	2⅜	2½	2¾	2¾
Columns,														
Diameter at top	4	4¾	5⅛	5½	6	7	8	8¼	9⅛	9¼	9½	10	10¼	10½
Diameter at bottom	4½	5½	6¼	6⅜	6¾	7¾	9	9⅜	10½	10¾	11	11½	11¾	12
Centre to centre of														
Air-pump, side rods transversely	29½	34¼	37¼	39½	42¼	47½	53	55¾	60¾	63	67	68½	70	72
Beams, do.	33	39	42½	45	48	54	60	63	69	69	72	78	80	83
Frames, do.	21	23	25½	26	27	30	34	34	40	40	42	44	45	46
Engines, do.	66	72	76	80	84	88	96	100	108	108	112	126	128	130
Length of steam port	7½	8¾	10	11	11½	13	15	18½	18½	19	19	20	20	21
Breadth of steam port	1½	1¾	2	2¼	2½	2¾	3	3	4	4	4¼	4½	4¾	4¾
Fort valve passage, depth	2	2	2½	2½	3¼	3¾	4	4½	5	5¼	5½	6	6½	7
" " width	13	14	15½	17	18	20	24	26	28	28	29	31	31	32
Beam,														
Breadth at middle	14	18	19	21	23	25	28	29	33	34	35	36	38	39
Breadth at ends	5	6	6¾	7½	8	8¾	10	10½	12	12¼	12¾	14	15	15½
Thickness	1	1⅛	1½	1⅜	1½	1¾	1⅞	2	2¼	2⅜	2½	2½	2½	2⅝

TABLES OF DIMENSIONS, *&c., of* 63 STEAM VESSELS, *and of their* ENGINES *and* PROPELLERS; *selected from a more extended list, with the view of presenting only those of which the complete particulars are recorded.*

NOTE.—The tonnage is according to the old builders' measurement. In the column showing the material of each vessel the letter W. signifies *Wood*, and I. *Iron*.

Number.	Name of Vessels.	Date of launch.	Material.	Tonnage.	Length. Over all.	Length. Of keel.	Length. Between perpendiculars.	Depth.	Mean draught.	Extreme breadth.
					ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
1	Actæon, &c.	1837	W.	552	...	...	171 0	17 3	10 0	25 10
2	Agir	1841	I.	254½	150 0	...	145 0	10 1	5 8	19 0
3	Alice	1839	I.	170	...	...	95 0	9 0	4 6	20 0
4	Arcadia, &c.	1840	W.	1200	228 0	...	206 0	22 6	16 6	34 6
5	Archimedes	1836	W.	237	125 0	...	107 0	13 0	9 4	22 6
6	Avon and Severn	1841	W.	1354	238 0	...	213 0	30 6	17 6	36 6
7	Berenice	1836	W.	646	...	148 5	164 10	20 0	13 0	28 8
8	Black Eagle	...	W.	496	...	136 9	155 0	14 10	10 6	26 1
9	Blackwall	1842	I.	258½	...	...	145 0	9 10	5 0	19 1
10	British Queen	1838	W.	1862	275 0	...	...	27 6	17 0	40 0
11	Clyde, &c.	1841	W.	1354	238 0	...	213 0	23 6	17 6	36 6
12	Colchis, &c.	1837	W.	433½	...	...	156 0	13 6	9 6	24 0
13	Cormorant	1843	W.	1110	210 0	...	180 0	21 0	...	36 0
14	Courier	1841	I.	310	158 water line		...	9 0	1 4	20 0
15	Cyclops	1839	W.	1195	216 6	...	...	23 0	15 6	35 6
16	Dart	...	I.	48	...	...	81 0	7 0	2 3	11 0
17	Dee, &c.	1841	W.	1354	...	...	213 0	30 6	17 6	36 6
18	Devastation	1841	W.	1100	210 0	...	180 0	21 0	...	36 0
19	Dolphin	1839	I.	107	...	...	110 0	7 6	2 3	14 0
20	Dundalk	1834	I.	560	...	170 fore rake		16 0	10 6	26 0
21	Dundee, &c.	1834	W.	650	...	...	170 0	17 6	11 6	28 0
22	Eclipse	1840	I.	277⅔	...	...	156 0	11 0	5 6	19 0
23	Enterprise	1839	I.	92	...	...	76 6	8 0	3 9	16 0
24	Era	...	I.	60	...	...	85 0	5 11	2 5	12 0
25	Fairy	1845	I.	260	145 0	...	...	10 6	5 0	21 0
26	Father Thames	1840	I.	247	...	...	140 0	10 0	4 0	19 0
27	Fulton	...	W.	...	181 6	deck	...	...	10 0	34 6
28	Grappler	1845	I.	557	...	...	165 0	17 0	10 0	26 6
29	Great Britain	1844	I.	3443	320 0	289 0	...	32 6	16 0	51 0
30	Great Liverpool	1837	W.	1140½	...	209 5	...	19 8	16 0	30 10
31	Great Northern	1842	W.	1430	247 0	...	221 0	26 0	18 0	37 0
32	Great Western	1838	W.	1321	236 0	...	...	23 3	16 0	35 4
33	Hamlet	1842	I.	130	...	...	96 0	9 6	5 6	17 0
34	Herne	1844	I.	355	...	...	155 6	10 0	6 2	21 6
35	Hibernia	1842	W.	1350	...	218 fore rake		24 0	17 6	36 0
36	India	...	W.	1000	...	189 0	...	28 0	...	32 0
37	Invincible	1844	I.	...	...	125 0	...	8 0	5 6	17 3
38	Isis and Trent	1841	W.	1298½	...	...	215 0	23 0	17 3	36 0
39	Lady Burgoyne	1843	I.	...	...	...	126 0	9 6	4 9	17 6
40	Locomotive	1841	I.	70	...	...	105 0	6 6	2 6	11 6
41	Medea	1843	W.	807	...	...	179 4	20 0	14 0	31 11
42	Nimrod	1843	I.	591	...	175 0	180 0	16 0	11 0	26 0
43	Nile	...	W.	911	180 0	deck	...	20 6	13 6	33 0
44	Northern Light Yacht	1845	I.	303½	146 3	deck	142 0	12 9	6 0	21 0
45	Peloro	1843	W.	252	...	...	130 0	11 2	...	20 2½
46	Penelope	1842	W.	1630	215 main deck		...	25 0	...	40 0
47	Precursor	1841	W.	1476	244 0	...	225 0	25 0	17 0	37 0
48	President	1840	W.	1840	265 0	...	...	30 0	17 0	41 0
49	Prince Albert	...	I.	300	...	...	155 0	9 6	4 6	19 6
50	Prince of Wales	1842	I.	585	...	...	160 0	15 6	7 9	26 6
51	Princess Royal	1841	I.	800	...	185 0	...	17 0	10 0	28 0
52	Princess Alice	1843	I.	260	145 0	...	...	10 6	6 6	20 0
53	Railway	1842	I.	258½	...	...	145 0	9 10	5 3	19 1
54	Rainbow	1837	I.	581	...	...	190 0	12 0	6 0	25 0
55	Retribution	1844	W.	1710	...	192 10	220 0	26 4	18 0	40 6
56	Rocket	1842	I.	70½	...	...	90 0	7 4	...	12 8
57	Rose, &c.	1840	I.	306	...	...	148 0	11 6	6 6	20 6
58	Ruby	1836	W.	272¼	..	141 9½	155 0	10 2	4 6	19 0
59	Styx, &c.	1839	W.	1057	180 0	deck	...	21 0	14 9	36 2
60	Thunderbolt	1842	W.	...	174 0	deck	...	21 0	14 6	36 0
61	Vernon	1841	W.	1000	...	...	170 0	22 0	15 6	36 0
62	Water Witch	...	I.	...	...	123 0	...	5 6	2 9	16 4
63	William Wilberforce	1840	W.	650	200 0	...	...	17 0	10 0	27 0

PROPELLING MACHINERY.

NOTE.—In the last column, showing the description of engines, the abbreviations S. L. signify *Side Lever;* D. A. *Direct Action;* O. *Oscillating;* St. *Steeple;* D. C. *Double Cylinder;* H. P. *High Pressure.*

Number.	Number of engines.	Horse power of each engine.	Diameter of cylinders.	Stroke. Length.	Stroke. No. per minute.	Diameter.	Paddle wheel's boards.	Kind of engines.
			in.	ft. in.		ft. in.	ft. in. ft. in.	
1	2	146	[illegible]	5 9	20	24 6	8 10 × 2 3	
2	2	41	56¾	3 0	30	16 0	7 6 × 1 4	S. L.
3	2	30	31	3 3	...	14 0	......	D. A.
4	2	210	72	6 10	16	28 0	9 0 × 3 0	S. L.
5	2	42	37	3 0	26	......	screw	
6	2	230		7 0	16	30 0	......	S. L.
7	2	118	56	5 6	21	23 0	8 6 × 2 1	S. L.
8	2	135	62	4 6	...	23 0	5 6 × 4 0	O.
9	1	92	55	3 0	31	15 6	9 10 × 1 2	St.
10	2	244½	77½	7 0	16	30 0	9 6 × 2 8½	S. L.
11	2	230	74¼	7 6	15	30 0	......	S. L.
12	2	62	42	4 6	23	17 0	8 0 × 1 9	S. L.
13	2	158	65½	5 3	22	26 8	8 3 × 2 0	D. A.
14	2	35	34	3 0	28	15 0	8 0 × 1 1¾	O.
15	2	154	64	5 6	21	26 0	8 0 × 1 10	D. A.
16	2	10¾	20	2 0	35	11 0	4 6 × 0 11	
17	2	217	73	7 0	16	28 6	9 6 × 2 6	S. L.
18	4	112	54 1–16th	6 0	18	26 0	9 0 × 2 1	D. C.
19	2	21	28	2 0	35	10 4	4 3 × 1 6	S. L.
20	2	140	61	5 6	21	24 9	8 8 × 2 1	S. L.
21	2	126	58	5 6	21	24 0	8 0 × 2 2	S. L.
22	1	100	54½	4 0	28	16 6	9 0 × 1 3	St.
23	2	21	27¼	2 6	34	12 6	5 4 × 1 2	S. L.
24	2	12	17⅜ and 29	1 8	34	10 4	5 0 × 1 0	D. C.
25	2	54	42	3 0	50	......	screw	O.
26	2	37½	35	3 0½	30	18 6	8 6 × 1 3	O.
27	2	250	50	9 0	25	22 5	11 6 × 3 0	
28	4	110	40	4 6	25	21 0	8 0 × 1 6	D. C.
29	4	300	88	6 0	18½	......	screw	
30	2	229	75	7 0	16	28 5	......	S. L.
31	2	162	68	4 6	22	......	screw	
32	2	220	73½	7 0	16	28 9	10 0 × 2 6	S. L.
33	2	21	27½	2 3	38	11 0	5 6 × 1 3	S. L.
34	2	60	43½	3 6	29	18 6	11 0 × 1 6	S. L.
35	2	250	77½	7 6	15	30 4	10 0 × 3 0	S. L.
36	2	151	63	5 9	20	26 6	8 0 × 2 3	S. L.
37	1	83	49	4 2	31⅓	16 0	5 8 × 1 2	St.
38	2	225	74¼	7 0	15	29 0	10 0 × 3 0	S. L.
39	2	46	39	3 0	32	16 0	8 0 × 1 4	O.
40	2	...	51	4 0	27	......	......	H. P.
41	2	112	55½	5 0	22	24 0	5 8 × 4 6	S. L.
42	2	160	66	5 3	22	24 6	8 6 × 2 7	D. A.
43	2	132	60	5 2	22	22 0	9 7 × 2 9	S. L.
44	2	76	47	4 3	25	19 0	7 6 × 1 10	O.
45	2	50	39½	3 6	29	15 6	8 0 × 1 4	S. L.
46	2	320	91	6 0	18	30 0	10 0	D. A.
47	2	260	80	7 0	16	28 0	......	S. L.
48	2	266	80	7 6	15	31 0	......	S. L.
49	2	50	40	3 4	32	17 6	9 0 × 1 4	D. A.
50	2	135	61	5 0	22	25 0	6 9 × 2 0	St.
51	2	208	73	6 3	17	29 0	7 9 × 2 4	St.
52	2	60	48	3 6	30	18 5	7 0 × 2 3	D. A.
53	2	46	39	3 0	33	15 6	9 8 × 1 2	O.
54	2	88	50	4 6	25	21 0	9 10 × 1 8	St.
55	4	400	72	6 0	...	34 0	13 0 × 2 6	D. C.
56	2	10	19	2 0	40	9 8	3 8 × 0 10	O.
57	2	53	40¾	3 6	29	17 0	8 0 × 1 6	S. L.
58	2	51½	40	3 6	30	17 6	9 2 × 1 3	S. L.
59	2	142	62	5 3	20	26 0	8 3 × 1 10	D. A.
60	2	163	67	5 0	20	26 0	7 10	D. A.
61	1	28	30	3 0	32	14 0	......	S. L.
62	2	16½	22	4 0	45	10 0	......	D. A.
63	2	140	60	6 0	20	24 0	8 6 × 2 0	S. L.

The following are considered in England the most approved proportions for steam vessels:—

Length of keel	1.
Breadth of beam	$\frac{1}{6}$th.
Depth of vessel	$\frac{1}{10}$th.

Centre of paddle boxes $\frac{3}{8}$ths from the stern end of the keel, and $\frac{5}{8}$ths from the stern post.

LOCOMOTIVE ENGINES.—Table *containing the velocity of the pistons, that of the circumference of the driving wheels being taken as* 1.

Stroke of the Pistons.	Diameters of Driving Wheels.								
in.	4ft. 0in.	4ft. 6in.	5ft. 0in.	5ft. 6in.	6ft. 0in.	6ft. 6in.	7ft. 0in.	7ft. 6in.	8ft. 0in.
20	0.2652	0.2393	0.2122	0.1929	0.1768	0.1632	0.1516	0.1414	0.1326
19	0.2519	0.2273	0.2016	0.1832	0.1679	0.1550	0.1440	0.1343	0.1259
18	0.2386	0.2153	0.1910	0.1736	0.1591	0.1468	0.1364	9.1272	0.1194
17	0.2254	0.2034	0.1803	0.1640	0.1503	0.1387	0.1288	0.1202	0.1127
16	0.2121	0.1914	0.1697	0.1543	0.1415	0.1305	0.1213	0.1131	0.1061
15	0.1989	0.1795	0.1591	0.1447	0.1326	0.1224	0.1137	0.1060	0.0994
14	0.1856	0.1675	0.1485	0.1350	0.1237	0.1141	0.1061	0.0990	0.0928
13	0.1724	0.1555	0.1379	0.1254	0.1149	0.1061	0.0985	0.0919	0.0862
12	0.1591	0.1436	0.1273	0.1157	0.1061	0.0979	0.0909	0.0848	0.0796

Application of this table for finding the tractive power of locomotive engines.—Multiply the sum of the areas of the two pistons by the *effective pressure* of the steam in pounds, and further, that product by the coefficient in the table (belonging to its driving wheels and stroke of the pistons), and this new product will be the traction of the engine in pounds.

Ex. A locomotive engine to have 5 feet 6 inch driving wheels, cylinders of 13 inches diameter by 18 inches stroke, and the effective pressure of the steam to be 40 lbs. on the square inch: what is its traction?

$$\frac{(2 \times 132.66)\ 40 \times 0.1736}{1842.39 \text{ lbs. of traction.}}$$

If it be required to know the number of tons the engine is able to draw on a level, divide its traction by the *friction* in pounds.

If the engine is to go up inclines, then add to that friction the *gravity* in pounds due to a ton on that incline, and use this sum as a divisor for the traction: the quotient will be the number of tons the engine is capable to rise up that incline with. In both cases is the weight of the engine and its tender in the quotient included.

Explanations.—By *effective pressure* is understood the pressure of the steam above the pressure of the atmosphere, less the number of pounds necessary to keep the engine by itself just in motion.

Friction, the power necessary to move a mass along, which is generally taken to be, on railways, equal to 10 lbs. for every ton.

Gravity, the power to overcome the tendency of a mass or load to descend an incline, being always equal to the quotient of the product of the load, and height of the incline, divided by the length of the incline.

Therefore the above engine would draw

$$\frac{1842.39}{10} = 184 \text{ tons on a level;}$$

and, on an incline, say as 1 in 300,

$$\text{Friction} = 10 \text{ lbs.}$$

$$\text{Gravity} = \frac{1 \times 2240}{300} = \frac{7.466 \text{ lbs.}}{17.466 \text{ lbs.}} \quad \text{Consequently,}$$

$$\frac{1842.39}{17.466} = 105.5 \text{ tons up an incline of 1 in 300.}$$

If the weight of the engine, with its tender, be taken at 18 tons, it will draw a net gross load of

166 tons on a level, and

87.5 tons up an incline of 1 in 300.

TABLE *showing the Speed of an Engine, when the time of performing a ¼, ½, or 1 Mile, is given.*

Speed per hour.	Time of performing ¼ mile.		Time of performing ½ mile.		Time of performing 1 mile.		Speed per hour.	Time of performing ¼ mile.		Time of performing ½ mile.		Time of performing 1 mile.	
Miles.	min.	sec.	min.	sec.	min.	sec.	Miles.	min.	sec.	min.	sec.	min.	sec.
5	3	0	6	0	12	0	53	0	17.	0	34.	1	7.9
6	2	30.	5	0	10	0	54	0	16.7	0	33.3	1	6.6
7	2	8.6	4	17.2	8	34.3	55	0	16.4	0	32.7	1	5.4
8	1	52.5	3	45.	7	30.	56	0	16.1	0	32.1	1	4.3
9	1	40.	3	20.	6	40.	57	0	15.8	0	31.6	1	3.1
10	1	30.	3	0	6	0	58	0	15.5	0	31.	1	2.
11	1	21.8	2	43.6	5	27.3	59	0	15.2	0	30.5	1	1.
12	1	15.	2	30.	5	0	60	0	15.	0	30.	1	0
13	1	9.2	2	18.4	4	37.	61	0	14.7	0	29.5	0	59.
14	1	4.3	2	8.6	4	17.1	62	0	14.5	0	29.	0	58.
15	1	0	2	0	4	0	63	0	14.3	0	28.5	0	57.
16	0	56.2	1	52.4	3	45.	64	0	14.1	0	28.1	0	56.2
17	0	52.9	1	46.	3	31.8	65	0	13.8	0	27.7	0	55.4
18	0	50.	1	40.	3	20.	66	0	13.6	0	27.2	0	54.5
19	0	47.4	1	34.8	3	9.5	67	0	13.4	0	26.9	0	53.7
20	0	45.	1	30.	3	0	68	0	13.2	0	26.5	0	52.9
21	0	42.8	1	25.6	2	51.4	69	0	13.	0	26.1	0	52.2
22	0	40.9	1	21.8	2	43.6	70	0	12.8	0	25.7	0	51.4
23	0	39.1	1	18.2	2	36.5	71	0	12.7	0	25.3	0	50.7
24	0	37.5	1	15.	2	30.	72	0	12.5	0	25.	0	50.
25	0	36.	1	12.	2	24.	73	0	12.3	0	24.6	0	49.3
26	0	34.6	1	9.2	2	18.4	74	0	12.1	0	24.3	0	48.6
27	0	33.3	1	6.6	2	13.3	75	0	12.	0	24.	0	48.
28	0	32.1	1	4.3	2	8.6	76	0	11.8	0	23.7	0	47.3
29	0	31.1	1	2.1	2	4.1	77	0	11.7	0	23.4	0	46.7
30	0	30.	1	0	2	0	78	0	11.5	0	23.1	0	46.1
31	0	29.	0	58.	1	56.1	79	0	11.4	0	22.8	0	45.6
32	0	28.1	0	56.2	1	52.5	80	0	11.2	0	22.5	0	45.
33	0	27.3	0	54.6	1	49.1	81	0	11.1	0	22.2	0	44.4
34	0	26.5	0	53.	1	46.	82	0	10.8	0	21.9	0	43.9
35	0	25.7	0	51.4	1	43.	83	0	10.8	0	21.7	0	43.4
36	0	25.	0	50.	1	40.	84	0	10.7	0	21.5	0	43.
37	0	24.3	0	48.6	1	37.3	85	0	10.6	0	21.2	0	42.3
38	0	23.7	0	47.4	1	34.3	86	0	10.5	0	20.9	0	41.9
39	0	23.	0	46.1	1	32.3	87	0	10.3	0	20.7	0	41.4
40	0	22.5	0	45.0	1	30.	88	0	10.2	0	20.4	0	40.9
41	0	21.9	0	43.9	1	27.8	89	0	10.1	0	20.2	0	40.4
42	0	21.4	0	42.8	1	25.7	90	0	10.	0	20.	0	40.
43	0	20.9	0	41.9	1	23.7	91	0	9.9	0	19.7	0	39.5
44	0	20.4	0	40.9	1	21.8	92	0	9.8	0	19.5	0	39.1
45	0	20.0	0	40.	1	20.	93	0	9.7	0	19.3	0	38.7
46	0	19.5	0	39.1	1	16.6	94	0	9.6	0	19.1	0	38.3
47	0	19.1	0	38.3	1	16.6	95	0	9.5	0	18.9	0	37.9
48	0	18.7	0	37.5	1	15.	96	0	9.4	0	18.7	0	37.5
49	0	18.3	0	36.7	1	13.4	97	0	9.3	0	18.5	0	37.1
50	0	18.	0	36.	1	12.	98	0	9.2	0	18.4	0	36.7
51	0	17.6	0	35.3	1	10.6	99	0	9.1	0	18.2	0	36.4
52	0	17.3	0	34.6	1	9.2	100	0	9.	0	18.	0	36.

NOTE.—If the distance of a journey, and the time it was performed in, be given, and the speed per hour be required, divide the time elapsed by the distance, and look in the table for the nearest speed belonging to that quotient.

Example. A distance of 31 miles was performed in 57 minutes; it is required to know the average speed per hour.

$$\frac{57}{31} = 1 \text{ minute } 50.3 \text{ seconds.}$$

The nearest speed in the table to that time is 33 miles.

TABLE *showing the Circumferences of different Driving Wheels.*

Diam. of Wheel.		Length of Circumference.	Diameter of Wheel.		Length of Circumference.
ft.	in.	feet.	ft.	in.	feet.
4	0	12·566	6	6	20·419
4	6	13·927	7	0	21·990
5	0	15·707	7	6	23·561
5	6	17·278	8	0	25·132
6	0	18·849			

TABLE *showing the Number of Revolutions of the Driving Wheels, or strokes of the Piston, per minute while the Engine is performing a known number of miles per hour.*

Diam. of Wheel 4 ft.	Diam. of Wheel 4 ft. 6 in.	Diam. of Wheel 5 ft.	Diam. of Wheel 5 ft. 6 in.	Diam. of Wheel 6 ft.	Diam. of Wheel 6 ft. 6 in.	Diam. of Wheel 7 ft.	Diam. of Wheel 7 ft. 6 in.	Diam. of Wheel 8 ft.	Number of miles performed per Hour.
No. of revolutions or strokes per min.	No. of revolutions or strokes per min.	No. of revolutions or strokes per min.	No. of revolutions or strokes per min.	No. of revolutions or strokes per min.	No. of revolutions or strokes per min.	No. of revolutions or strokes per min.	No. of revolutions or strokes per min.	No. of revolutions or strokes per min.	
35·03	31·59	28·03	25·47	23·34	21·55	20	18·67	17·5	5
70·06	63·17	56·06	50·95	46·68	43·10	40	37·34	35·0	10
105·09	94·76	84·09	76·42	70·02	64·65	60	56·01	52·5	15
140·12	126·36	112·12	101·70	93·36	86·20	80	74·68	75·0	20
175·15	157·95	140·20	127·37	116·70	107·75	100	93.35	87·5	25
210·18	189·54	168·18	152·85	140·04	129:30	120	112·02	105·0	30
245·21	221·13	196·21	177·29	163·38	150·85	140	130·69	122·5	35
280·24	252·72	224·24	203·76	186·72	172·40	160	149·36	140·0	40
315·27	284·30	252·27	229·23	210·06	193·95	180	168·03	157·5	45
350·30	315·90	280·30	254·75	233·40	215·50	200	186·70	175·0	50
385·33	347·49	308·33	280·17	256·74	237·05	220	205·37	192·5	55
420·36	379·08	336·36	305·64	280·08	258·60	240	224·04	210·0	60
455·39	416·67	364·39	331·11	303·42	280·15	260	242·71	227·5	65
490·42	442·19	392·42	356·58	326·76	301·70	280	261·38	245·0	70
525·45	473·85	420·50	372·05	350·10	323·25	300	280·05	262·5	75
560·48	505·50	448·48	407·60	373·44	344·80	320	298·72	280·0	80
595·51	536·89	477·01	432·99	396·78	366·35	340	317·39	297·5	85
630·54	568·60	504·51	458·55	420·12	387·90	360	336·06	315·0	90
665·57	600·19	532·57	483·93	443·46	409·45	380	354·73	332·5	95
700·60	631·78	560·63	509·50	466·80	431·00	400	373·40	350·0	100

NOTE.—To find the velocity the piston is travelling at in feet, per minute, multiply the number of revolutions of its driving wheels, in the table, by twice the length of its stroke in feet.

Ex. What is the speed of the piston of an engine with 6-feet driving wheels and 15-inch stroke, when going at the rate of 50 miles an hour?

By means of the table:

$$233{\cdot}4 \text{ revolutions} \times \left(2 + \frac{5}{4}\right) = 583{\cdot}5 \text{ feet per minute.}$$

The number of revolutions of driving wheels is inversely as their diameters, and in direct proportion to the number of miles performed.

Ex. How many revolutions have the driving wheels of an engine to make when it is going at 95 miles an hour, their diameter being 9 feet 6 inches?

According to the table, a 4-feet wheel would have to make 665·57 revolutions; therefore

$$9{\cdot}5 : 4 :: 665{\cdot}57 : \frac{4 \times 665{\cdot}57}{9{\cdot}5} = 280 \text{ revolutions.}$$

The driving wheels of an engine make 35·03 revolutions when going at the rate of 5 miles an hour how many will they make when going at 9 miles?

$$5 : 9 :: 35{\cdot}03 : \frac{9 \times 35{\cdot}03}{5} = 63{\cdot}05 \text{ revolutions.}$$

TABLE *of the Areas of Cylinders, from* 9 *to* 15 *inches diameter.*

Diameter of Cylinder.	Area of Cylinder.	Diameter of Cylinder.	Area of Cylinder.
Inches.	Square Inches.	Inches.	Square Inches.
9	63·58	12½	122·65
10	78·5	13	132·66
10½	86·56	13½	143·02
11	95·01	14	153·96
11½	103·84	14½	165·04
12	113·07	15	176·62

TABLE *containing the Speed of a Locomotive Engine, in feet per minute, when the rate it is going at in miles per hour is given.*

Miles performed per hour.	Velocity in feet per minute.	Miles performed per hour.	Velocity in feet per minute.	Miles performed per hour.	Velocity in feet per minute.	Miles performed per hour.	Velocity in feet per minute.
2	176	28	2364	54	4752	80	7040
4	352	30	2640	56	4928	82	7216
6	528	32	2816	58	5104	84	7392
8	704	34	2992	60	5280	86	7568
10	880	36	3168	62	5456	88	7744
12	1056	38	3344	64	5632	90	7920
14	1232	40	3520	66	5808	92	8096
16	1408	42	3696	68	5984	94	8272
18	1584	44	3872	70	6160	96	8448
20	1760	46	4048	72	6336	98	8624
22	1936	48	4224	74	6512	100	8800
24	2112	50	4400	76	6688		
26	2288	52	4576	78	6864		

Application of this table for finding the *useful effect* of an engine.

RULE.—Multiply the resistance of the weight or *friction* of the train in pounds, by the speed of the engine in feet per minute, and divide the product by 33000.

Ex. An engine to which are attached 6 carriages, weighing altogether 24 tons, going at the rate of 50 miles an hour, what is its useful effect?

$$\frac{(10 \times 24) \times 4400}{33000} = 32 \text{ horses' power.}$$

MARINE ENGINES.—WITH SIDE WHEELS.

CONDENSING.—For 550 square feet of immersed section, with a displacement of 2800 tons.

Cylinders. Two, each of 215 cubic feet in capacity.
Condensers. 75 cubic feet in each. *Air-pumps.* 50 cubic feet in each.
Force Pumps. $7\frac{1}{4}$ inches diameter by 46 inches stroke.
Water Wheels. 28 feet in diameter by 11 feet in width, 21 arms in each; buckets, (divided both in depth and length,) 14 and 16 inches.
Shafts, (wrought-iron.) Diameters of journals, $17 \times 18\frac{1}{2}$, and 12×15 inches.
Boilers. 6000 square feet of fire and flue surface; flues 40 feet in length, including steam chimney.
Grates. 260 square feet. *Steam Room.* 1770 cubic feet.
Pressure. Average, 10 lbs. per square inch, cut off at $\frac{1}{3}$ of the stroke of the piston: attainable, 20 lbs
Revolutions. From 12 to $18\frac{3}{4}$ per minute. *Dip of Wheel.* 5 feet at load-line.
Consumption of Fuel. 35 to 40 tons of bituminous coal per day.
Weights. Engines, boilers, water wheels, water in boilers, coal bunkers, engineers' stores, tools, &c., &c., 490 tons of 2240 lbs., viz.:—

Engines	211 tons.	Water wheels	47 tons.
Boilers and smoke pipe	120 "	Engineer's stores, tools, &c.	7 "
Water in boilers	82 "	Coal bunkers	23 "

Hull. Launching weight, 1280 tons.

CONDENSING.—For 200 square feet of immersed section, with a displacement of 650 tons. Length, 162·5 feet between perpendiculars; 27 feet beam; and 12 feet depth of hold. Load-line, 8·25 feet.

Cylinders. Two, each of 56·5 cubic feet in capacity.
Pressure. 16 lbs. per square inch, cut off at $\frac{1}{2}$ the stroke.
Revolutions. 22 per minute.
Water Wheels. 21 feet in diameter by 7·5 feet face, with 16 arms. *Dip.* 2·5 feet.
Buckets. 16 and 10 inches in depth.
Boilers. 1900 square feet of fire and flue surface. *Grates.* 84 square feet. *Steam Room.* 430 cubic feet.
Fuel, (natural draught.) At 19 revolutions, 1750 lbs. of anthracite coal per hour.

Weights.

Engines and frames	196,000 lbs.	Water in boilers	50,000 lbs.
Boilers and Chimney	68,000 "	Tools and stores, &c.	4,500 "
Coal bunkers	16,000 "		334,500 lbs.

Weights of metals in engines, (unfinished.)

Cast-iron	100,500 lbs.	Composition	11,300 lbs.
Wrought-iron	82,000 "	Copper	6,700 "

Hull. Wrought-iron, weighing 507,387 lbs

"Great Western." Condensing.—For 2372 tons displacement, (load-line,) with an area of immersed section of 480 square feet. Length between perpendiculars, 212 feet; beam, 35 feet 4 inches depth of hold, 23 feet 2 inches; draught of water, 17 feet.

Cylinders. 73½ inches in diameter by 7 feet stroke of piston. *Pressure.* 3½ lbs. per square inch *Revolutions.* 12½ per minute.

Water Wheels. 28 feet in diameter by 10 feet face. *Buckets.* 20 and 10 inches in depth.

Tonnage. Vessel, 1340 tons. Engine room, 641·5, or one-half of the whole.

Weights. Engines, 300 tons. Boilers, 100. Water in boilers, 80. Total, 480.

Centre to centre of engines, 13 feet.

H. M. Retribution." Condensing.—For 1641 tons burden, with 600 square feet of immersed section. Length between perpendiculars, 220 feet; beam 40 feet 6 inches; depth of hold, 26 feet 4 inches.

Cylinders. Four, of 72 inches in diameter by 8 feet stroke of piston, (direct action.)

Water Wheels. 33 feet in diameter by 13 feet in width. *Revolutions.* 15 per minute. *Dip of buckets,* 7 feet; depth, 30 inches.

Boilers. Four, containing 3418 square feet of fire and flue surface, 2272 cubic feet of steam room, and 704 cubic feet in furnaces, over the grate-bars.

Length of engine-room, 75 feet.

SCREW PROPELLER, (ERICSSON.)

Condensing.—For 338 square feet of immersed section, with a displacement of 1046 tons.

Length, 156·5 feet between perpendiculars; beam, 30·5 feet; hold, 21·5 feet; tonnage, 673$\frac{5}{95}$.

Cylinders. Two, each of 54 cubic feet in capacity. *Pressure.* 25 lbs. per square inch, cut off at ½ of the stroke.

Propeller. 120 square feet of surface. *Pitch.* 35 feet. *Diameter.* 14 feet. *Revolutions.* 36 per minute.

Shafts, (wrought-iron.) Diameter of journals, 12 × 16 inches.

Boilers. 2500 square feet of fire and flue surface. Flues, 50 feet in length. *Grates.* 134 square feet. *Steam Room.* 1150 cubic feet.

Fuel. 1 ton of anthracite coal per hour, (blast.)

Weights.

Engines	92 tons.	Water in boilers	34 tons.
Boilers	17 "	Coal bunkers	6 "

Hull. Launching weight, 418 tons. *Sails.* Area in square feet, 11,762. *Surface* of sails in proportion to immersed section, 34·92 square feet to 1.

RIVER ENGINES.—WITH SIDE WHEELS.

"Niagara." Condensing.—For 123 square feet of immersed section. Length of vessel, 265 feet; beam, 28 feet 6 inches; depth of hold, 9 feet 3 inches; draught, (loaded,) 4 feet 9 inches.

Cylinder. 216 cubic feet in capacity. *Condenser.* 88 cubic feet. *Air-pump.* 33·5 cubic feet.

Force-pumps. 5½ inches diameter by 4½ feet stroke.

Pressure. 40 to 45 lbs. per square inch, cut off at half the stroke of the piston. *Revolutions.* 24 per minute.

Water Wheels. 30 feet in diameter by 11 feet face. *Arms.* 24 in each flange. *Buckets.* Two, of 15 inches deep. *Dip, (at load-line.)* 30 inches.

Shafts, (wrought-iron.) Journal, 14 inches.

Boilers. Two, of 27 feet in length by 10 feet front. *Shell.* 8 feet 6 inches in diameter. *Fire and Flue Surface.* 3000 square feet. *Grates.* 108 square feet. *Steam Room.* 1200 cubic feet.

Fuel. 3200 lbs. of anthracite coal per hour, (maximum.)

Blowers. Two, of 9 feet in diameter. *Fans.* Ten, of 24 inches by 3 feet face.

Blowing-engines. Two, of 10 inches diameter of cylinder by 12 inches stroke. *Revolutions.* 150 per minute.

Weights.

Engines	186,000 lbs.
Boilers	65,000 "
Wood, in engines and wheels	29,000 "
Water in boilers	76,000 "
Total	356,000 lbs.

"South America." Condensing.—For 132 square feet of immersed section. Length of vessel, 250 feet; beam, 27 feet; depth of hold, 9 feet; draught, (loaded,) 5 feet.

Cylinder. 175 cubic feet in capacity. *Air-pump.* 38·5 cubic feet.

Condenser. 72 cubic feet. *Force-pumps.* 5 inches diameter by 4 feet stroke.

Pressure. 35 to 40 lbs. per square inch, cut off at half the stroke of the piston.

Revolutions. 23·5 to 23 per minute.

Water Wheels. 29 feet in diameter by 11 feet face. *Arms.* 24 in number. *Buckets.* Two divisions, and 30 inches deep. *Dip, (at load-line.)* 30 inches.

Shafts, (wrought-iron.) Diameter of journal, 13 inches.

Boilers. Two, 27 feet in length by 9·5 in width. *Fire and Flue Surface.* 3000 square feet. *Shell.* 8 feet in diameter. *Grates.* 100 square feet. *Steam Room.* 1000 cubic feet

Consumption of fuel. 3000 lbs. of anthracite coal per hour, (maximum.)

Blowers. Four, 4 feet diameter by 26 inches face. 4 arms. *Fans.* 13 inches deep. *Revolutions.* 75 per minute.

Blowing-engines. Cylinder, 8 inches in diameter by 12 inches stroke.

Weight of boilers. 62,000 lbs.

The above engines and boilers were designed and constructed at the Phœnix Foundry, New York.

Condensing.—For 160 square feet of immersed section. Length of vessel, 335 feet; beam, 35 feet, depth of hold, 11 feet 6 inches.

Cylinder. 313 cubic feet in capacity. *Air-pump.* 54 cubic feet.

Pressure. 38 lbs. per square inch. *Revolutions.* 22 per minute.

Water Wheels. 34 feet in diameter by 10 feet 8 inches face. *Buckets.* 30 inches deep.

Boilers. Shell. 9½ feet in diameter. *Surface.* 3660 square feet. *Steam Room.* 1570 cubic feet. *Grates.* 145 square feet.

Blowing-engines. Two *cylinders*, of 14 inches diameter by 14 inches stroke. Two *blowers.* 10 feet in diameter by 2 feet in width. Ten *fans* in each, of 26 inches in depth. *Revolutions.* 100 per minute.

Fuel. 3000 lbs. of anthracite coal per hour.

Non-Condensing. For 300 square feet of immersed section. Vessel 260 feet in length, 38 feet beam, and 8 feet draught when loaded.

Cylinders. Two, each 30 inches in diameter by 10 feet stroke of piston, (98·3 cubic feet.) *Force-pumps.* 6¾ inches in diameter by 25 inches stroke.

Water wheels. 33 feet in diameter by 15 feet in width, 19 arms in each. *Buckets.* 36 inches deep. *Shafts, (cast-iron.)* Diameter of journals, 16 and 14 inches.

Connecting-rod. 35 feet in length. *Piston-rod.* Diameter, 6 inches.

Steam valves. 50 square inches each. *Exhaust valves.* 63 square inches.

Boilers. Five, of 42 inches in diameter by 34 feet in length, with two return flues in each, 16 inches in diameter, having 2278 square feet of heating surface. *Grates.* 84 square feet.

Boiler plates. Shells. ¼ of an inch in thickness. *Flues.* Full ¼ of an inch.

Pressure. 75 to 100 lbs. per square inch, cut off at ⅜ the stroke of the piston.

Revolutions. 16 to 21 per minute. *Dip of wheel.* 5 feet when loaded.

Consumption of fuel. 2·3 cords yellow pine per hour.

Weights. Engines, 160 tons; boilers, 9000 lbs.

Non-Condensing.—Pressure of steam, 100 lbs. per square inch, cut off at ½ stroke. Revolutions, 22 per minute.

Cylinders. 42½ cubic feet. *Boilers.* 1393 square feet of fire and flue surface.

Water wheels. 22½ feet in diameter by 10 feet 4 inches face, with 13 inches depth of bucket.

Smoke pipe. 42 inches in diameter × 45 feet high. *Area of flues.* 1600 square inches.

Fuel. 36 cords western wood in 12 hours.

Furnace. 17 feet in width by 42 in length, and 17 inches in height. *Grates.* 68 square feet.

Note.—32·75 square feet of fire and flue surface is the proportion for each cubic foot in the cylinders at the above given revolutions.

STEAM VESSELS.—MARINE.

"Great Britain."—Displacement at 16 feet draught, 3000 tons. Length of keel, 289 feet; beam, 51 feet; depth of hold, 32 feet 6 inches.

Plates. ⅞, $\frac{11}{16}$, ⅝, and ⅜ thick.

Frames. 18 and 24 in. apart. ⅝ thick, by 3·5 × 6 inches; by 2·5 × 6 inches, and by 3 × 4 inches, ⊥.

Weight of Hull, (in iron.) 1040 tons.

"Michigan."—Displacement at 8 feet 8 inches draught, 658 tons. Length between perpendiculars, 162 feet 6 inches; beam, 27 feet; depth of hold, 13 feet.

Plates. ⅝, ½, ⅜, $\frac{5}{16}$, ¼, and $\frac{3}{16}$ thick.

Frames. 2 feet apart. ½ and ⅜ thick, by 4 × 4·5 inches, ⊥; and ½ and ⅜, by 4 × 2·25 inches, L.

Deck beams. ⅜, by 4·5 × 7 inches, ⊥.

Weight of Hull, including bulwarks and berth deck, 507,387 lbs.

"Spencer."—Displacement at 9 feet 3 inches, 440 tons. Length between perpendiculars, 143 feet beam, (average,) 20 feet 3 inches; depth of hold, 11 feet 6 inches.

Plates. ⅜, $\frac{5}{16}$, and ¼ of an inch.

Frames. 20 inches apart. ⅝ thick, by 2·5 × 4·5 inches, L.

Deck beams. ⅝, by 2·87 × 5·5 inches, L.

Weights.

Platin	125,922 lbs.	Knees	13,845 lbs.
Bulk-heads	11,663 "	Rivets	18,005 "
Keelson	3,093 "	Stanchions	2,997 "
Deck beams	34,463 "	Sundries	20,918 "
Frames	44,661 "	Total	275,567 lbs.

Canal Boat, (very full built.) Length between perpendiculars, 80 feet; beam, 14 feet; depth of hold, 7 feet

Plates. Nos. 3 and 4, wire gage.
Frames. 18 inches apart, and ⅜ thick by 3 inches wide, |.
Deck and beams of wood.

Weight of Hull, 42,300 lbs.

Sugar Mill. For expressing 20,000 lbs. of cane juice per day.—Non-Condensing Engine.

Cylinder. 15 inches in diameter by 4 feet stroke.
Pressure. 50 lbs. per square inch, cut off at ½ the stroke of the piston.
Revolutions. 36 per minute.
Boiler. One of 62 inches in diameter by 3C feet in length, with two 18 inch return flues. *Grates.* 34 square feet.
Rolls. Two sets of three each, of 24 inches in diameter by 5 feet in length; geered 2½ to 36 of engine, giving a speed of periphery of 15½ feet per minute.
Fly-wheel. 18 feet in diameter; weight, 5 tons.
This arrangement of a second set of rolls is a late improvement; its object, that of expressing the cane a second time. An increase of 30 per cent. is effected by it.

For a crop of 3000 boxes of sugar of 500 lbs. each.

A non-condensing engine, with a cylinder of 11 inches in diameter by 4 feet stroke, making 48 revolutions, with a pressure of steam 60 lbs. per square inch, driving one set of rolls, 24 inches by 4 feet, at a speed of periphery of 36 feet per minute.
Boiler. 52 inches by 24 feet, with two 16 inch return flues. *Grate surface.* 25 square feet.
Fly-wheel. 16 feet diameter; weight, 4 tons.

Saw-mill.—Non-Condensing Engine. Two vertical saws of 34 inches stroke. Lathes, &c.

Cylinder. 10 inches in diameter by 4 feet stroke.
Pressure. 90 to 100 lbs. per square inch, full stroke. *Revolutions.* 35 per minute.
Boilers. Three, plain cylindrical, 30 inches in diameter by 20 feet in length.
Note.—This engine has cut, of yellow pine, 30 feet by 18 inches in one minute.

Cotton Factory. Condensing Engine.—Driving 13,000 spindles, (mules and throstles,) with 256 looms for ¾ cloth No. 30.

Cylinders. Two, 22 inches in diameter by 3 feet stroke of piston.
Pressure. 15 to 45 lbs. per square inch, cut off at ½ of the stroke.
Revolutions. 50 per minute.

Condensing Engine, (British.) Driving 22,060 hand-mule spindles, with preparation, 260 looms, and common sizing.

Engine.—Cylinder, 37½ inches diameter by 7 feet stroke; indicated pressure (average) 16·73 lbs. per square inch, revolutions, 17 per minute.
Friction of engine and shafting, indicated 4·75 lbs. per square inch of piston.
Total power = 1. Available, deducting friction = ·717. Estimated power of engine, 134 horses.

Notes.—Each indicated horse power will drive

305 hand-mule spindles, with preparation,
or 230 self-acting " "
or 104 throstle " "
or 10½ looms with common sizing.

Including preparation:

1 throstle spindle = 3 hand-mule, or 2¼ self-acting spindles.
1 self-acting spindle = 1⅓ hand-mule spindles.

Exclusive of preparation, taking only the spindle:

1 throstle spindle = 3½ hand-mule, or 2⅝ self-acting spindles.
1 self-acting spindle = 1⅜ hand-mule spindles.

The *throstles* are the common, spinning 34 twist for power-loom weaving: the spindles revolve 4000 per minute. The self-acting mules are, one half spinning 36's weft, spindles revolving 4800; the other half spinning 36's twist, spindles revolving 5200. The *hand-mules* spinning about equal quantities of 36's weft and twist. Weft spindles 4700, and twist spindles 5000 revolutions per minute.
Average breadth of looms 37 inches, (weaving 37 inch cloth,) making 123 picks per minute. All common calicoes about 60 reed, Stockport count, and 68 picks to the inch.
No power consumed by the sizing. When the yarn is dressed instead of sized, one-horse power cannot drive so many looms, as the dressing machine will absorb from 1-6th to 1-7th of the power

Cotton Press. Non-Condensing Engine.—For 1000 bales in 12 hours

Cylinder. 14 inches in diameter by 4 feet stroke.
Pressure. 40 lbs. per square inch, at full stroke. *Revolutions.* 60 per minute.
Boilers. Three, plain cylindrical without flues, 30 inches in diameter by 26 feet in length. *Grates,* 32 square feet.
Presses. Four, geered 6 to 1, with two screws each of 7½ inches in diameter by 1⅝ inch pitch.
Shaft, (wrought-iron.) Journal, 8½ inches.
Fly-wheel. 16 feet in diameter; weight, 4 tons.

Blowing or Blast Engine.—Dimensions of a furnace, engines, &c. At Lonakoning, (Md.)

Furnace. Diameter at the boshes 14 feet, which fall in 6·33 inches in every foot rise.

Engine, (*Non-condensing.*) Diameter of cylinder 18 inches, length of stroke 8 feet. *Revolutions.* 12 per minute, with a pressure of 50 lbs. per square inch.

Boilers. Five, each 24 feet in length, and 36 inches in diameter.

Blast cylinders. 5 feet diameter and 8 feet stroke.

At a pressure of from 2 to 2½ lbs. per square inch, the quantity of blast is 3770 cubic feet per minute, requiring a power of about 50 horses to supply it.

For blowing four furnaces, 14 feet in diameter, each making 100 tons of pig iron per week. At Mount Savage, (Md.)

Engine, (*Condensing.*) Diameter of cylinder 56 inches, length of stroke 10 feet.

Revolutions. 15 per minute. *Pressure.* 60 lbs. per square inch, cut off at ¾ of the stroke.

Boilers. Six of 60 inches in diameter, and 24 feet in length, with one 22 inch flue in each, double returned. *Grates.* 198 square feet.

Blast cylinder. 126 inches in diameter by 10 feet stroke. *Revolutions.* 15 per minute.

Pressure of blast. 4 to 5 lbs. per square inch.

Area of pipes. 2300 square inches, or 1-5th that of the cylinder.

For blowing two furnaces and two fineries, making 240 tons of forge pig per week.

Engine, (*Non-condensing.*) Diameter of cylinder 20 inches, length of stroke 8 feet.

Revolutions. 28 per minute. *Pressure.* 50 to 60 lbs. per square inch, (full stroke.)

Boilers. Six of 36 inches in diameter and 28* feet in length, (without flues.) *Grates.* 100 square feet.

Blast-cylinders. Two of 62 inches in diameter by 8 feet stroke. *Revolutions.* 22 per minute. *Pressure of blast.* 2½ lbs. per square inch.

Area of pipes. 3 feet, or 1-6th that of the cylinders.

One blast furnace has two 3 inch and one 3¼ inch tuyeres, the other has three of 3 inches.

One finery has six tuyeres of 1⅛ inch, and the other, four of 1⅛ inch.

The ore yields from 40 to 45 per cent. of iron. The temperature of the blast is 600°.

PILE-DRIVING. NON-CONDENSING ENGINE.—Driving two piles.

Cylinders. Two of 6 inches in diameter by 18 inches stroke.

Pressure. 60 lbs. per square inch, full stroke. *Revolutions.* From 60 to 80 per minute.

Boiler. Tubular. *Shell.* 3½ feet in diameter by 6 feet in length. Furnace end, 3 feet 9 inches in width, 3½ feet in length, and 6 feet in height.

Rams. 1000 lbs. each, lifted five times in a minute.

Frame. 8½ feet in width by 26 feet in length. *Leaders.* 3 feet in width by 24 feet in height

STEAM-DREDGING MACHINE. NON-CONDENSING ENGINE.—For dredging 30 feet from water-line. Six full buckets per minute.

Cylinder. 12 inches in diameter by 5 feet stroke of piston.

Pressure. 60 to 70 lbs. per square inch, full stroke. *Revolutions.* 20 per minute, geered 30 of engine to 1 of buckets.

Boilers. Two of 20 feet in length by 36 inches in diameter, with one 15 inch return flue in each.

Ways. 55 ft. in length by 6 in width. *Buckets.* Ten of 28 inch. in width by 58 in length, and 14 in depth.

At a depth of 18 ft., ten buckets full of mud are discharged per minute, the engine making 30 revolutions.

NOTE.—This engine is geered too slow, being but 2½ to 1.

Hulls. Two of 50 feet in length, 12 feet in width, and 9 in depth each; connected on deck, space between for the ways, 7½ feet.

ENGRAVING.—*Engraving on Copper* is performed by cutting lines representing the subject on a copper-plate by means of a steel instrument ending in an unequal-sided pyramidal point, such instrument being called a graver or burin, without the use of aquafortis. Besides the graver there are other instruments used in the process; viz.—a scraper, a burnisher, an oil-stone, and a cushion for supporting the plate. In cutting the lines on the copper the graver is pushed foward in the direction required, being held in the hand at a small inclination to the plane of the copper. The use of the burnisher is to soften down lines that are cut too deep, and for burnishing out scratches in the copper: it is about three inches long. The scraper, like the last, is of steel, with three sharp edges to it, and about six inches long, tapering towards the end. Its use is to scrape off the burr, raised by the action of the graver. To show the appearance of the work during its progress, and to polish off the burr, engravers use a roll of woollen or felt called a rubber, which is put in action with a little olive-oil. The cushion, which is a leather bag about nine inches diameter filled with sand for laying the plate on, is now rarely used except by writing-engravers. For architectural subjects, or in skies, where a series of parallel lines are wanted, a ruling-machine is used: the accuracy of its operation is exceedingly perfect. This is made to act on an etching ground by a point or knife connected with the apparatus, and bit in with aquafortis in the ordinary way.

The plate of copper must be perfectly polished, very level, and free from every imperfection: to this must be transferred an exact copy of the outlines of the drawing. To do this the plate is heated in an oven or otherwise, very uniformly, till it is sufficiently hot to melt white wax, a piece of which is then rubbed over it and allowed to spread so as to form a thin coat over the whole surface, after which it is left in a horizontal position till the wax and plate are cold. A tracing being taken of the original design with a black-lead pencil on a piece of thin tracing-paper, this is spread over the face of the prepared plate with the lead lines downwards, and, being secured from slipping, a strong pressure is made use of by a press or otherwise, by which operation the lead lines are nearly obliterated on the paper, being transferred to the white wax on the plate. These pencil marks on the wax are now traced with

* 40 feet would have afforded much economy of fuel.

a fine steel point, so as just to touch the copper; the wax being then melted off, a perfect outline will be found on the copper; and on this the engraver proceeds to execute and finish his work. With respect to the process itself it would be useless to speak; it depends on manual dexterity and genius, which it is impossible to teach by description.

Engraving on Steel.—The method of engraving is the same as copperplate-engraving, except in certain modifications in the use of the acids, and therefore, so far as the process is concerned no particular description is necessary; but it will be proper to explain the means employed for decarbonizing the steel plate so as to reduce it to a proper state for being acted upon by the graving tool. Mr. Perkins, an eminent artist and engineer, (a native of Massachusetts,) has the merit of having established engraving on steel. About the year 1823 he was induced to visit London, where he obtained a patent for the invention; this was intended principally to prevent the forgery of bank notes, which at that time, or rather previously to that time, had been carried on to a very fearful extent. The method employed for decarbonizing and recarbonizing the plate may be applicable to many other useful purposes, and we shall therefore give it in the words of the patentee. "In order to decarbonate the surfaces of cast-steel plates, cylinders, or dies, by which they are rendered much softer and fitter for receiving either transferred or engraved designs, I use pure iron filings divested of all foreign or extraneous matters. The stratum of decarbonated steel should not be too thick for transferring fine and delicate engravings, for instance, not more than three times the depth of the engraving; but for other purposes the surface of the steel may be decarbonated to any required thickness. To decarbonate it to a proper thickness for a fine engraving, it is to be exposed for four hours in a white heat, enclosed in a cast-iron box with a well-closed lid. The sides of the box are made at least three-quarters of an inch in thickness, and at least a thickness of half an inch of pure iron filings should cover or surround the cast-steel surface to be decarbonated. The box is allowed to cool very slowly, which may be effected by shutting off all access of air to the furnace, and covering it with a layer of six or seven inches in thickness of fine cinders. Each side of the steel plate, cylinder, or die, must be equally decarbonated, to prevent it from springing or warping in hardening. It is also found that the safest way to heat the plates, cylinders, or dies, is by placing them in a vertical position. The best steel is preferred to any other sort of steel for the purpose of making plates, &c., and more especially when such plates, &c., are intended to be decarbonated. The steel is decarbonated solely for the purpose of rendering it sufficiently soft for receiving any impression intended to be made thereon; it is therefore necessary that after any piece of steel has been so decarbonated, whether it be in the shape of a plate, or a cylinder, or a die, it should, previously to being printed from, be again carbonated or reconverted into steel capable of being hardened. In order, therefore, to effect this decarbonization or reconversion into steel, the following process is employed: a suitable quantity of leather is to be converted into charcoal by the well-known method of exposing it to a red heat in an iron retort for a sufficient length of time, or until most of the evaporable matter is driven off the leather. Having thus prepared the charcoal, it is reduced to a very fine powder; then take a box made of cast-iron, of sufficient dimensions to receive the plate, cylinder, or die, which is to be reconverted into steel, so as that the intermediate space between the sides of the said box and the plate or die may be about an inch. This box is to be filled with the powdered charcoal, and, having covered it with a well-fitted lid, let it be placed in a furnace similar to those used for melting brass, when the heat must be gradually increased until the box is somewhat above a red heat; it must be allowed to remain in that state till all the evaporable matter is driven off from the charcoal; then remove the lid from the box, and immerse the plate, cylinder, or die, into the powdered charcoal, taking care to place it as nearly in the middle as possible, so that it may be surrounded on all sides by a stratum of the powder of nearly a uniform thickness. The lid being replaced, the box, with the plate, cylinder, or die, must remain in the degree of heat before described for from three to four hours, according to the thickness of the body so exposed; three hours are sufficient for a plate of half an inch in thickness, and five hours when the steel is one inch and a half in thickness. After the plate or other piece of steel has been thus exposed to the fire for a sufficient length of time, take it from the box and immediately plunge it into cold water. Here it is important to observe, that it is found by experience that the plates or other pieces of steel when plunged into cold water, are least liable to be warped or bent when they are held in a vertical position, or made to enter the water in the direction of their length. If a piece of steel, heated to a proper degree for hardening, be plunged into water, and suffered to remain there until it becomes cold, it is found by experience to be very liable to crack or break, and in many cases it would be found too hard for the operations it was intended to perform.

"If the steel cracks or breaks, it is spoiled. In order, therefore, to fit it for use, should it happen not to be broken in hardening, it is the common practice to heat the steel again, in order to reduce or lower its temper, as it is technically called. The degree of heat to which it is now exposed determines the future degree of hardness, or the temper, and this is indicated by a change of color upon the surface of the steel. During this heating a succession of shades is produced, from a very pale straw-color to a very deep blue. It is found, however, by long experience, that on plunging the steel into cold water, and allowing it to remain there no longer than is sufficient for lowering the temperature of the steel to the same degree as that to which a hard piece of steel must have been raised to temper it in the common way, it not only produces the same degree of hardness in the steel, but, what is of much more importance, almost entirely does away the risk or liability of its cracking or breaking. It is impossible to communicate by words, or to describe the criterion by which we can determine when the steel has arrived at the proper degree of temperature after being plunged into cold water; it can only be learned by actual observation, as the workman must be guided entirely by the kind of hissing or singing noise which the heated steel produces in the water while cooling. From the moment of its first being plunged into the water the varying sound will be observed; and it is at a certain tone, before the noise ceases, that the effect to be produced is known.

"The only directions which can be given whereby the experimentalist can be benefited, are as fol

lows: namely—to take a piece of steel which has already been hardened by remaining in the water till cold, and by the common method of again heating it to let it be brought to the pale yellow or straw color, which indicates the desired temper of the steel plate to be hardened. By the above process, as soon as he discovers this color to be produced, to dip the steel into water and attend carefully to the hissing, or as some call it a singing, which it occasions, he will then be better able, and with fewer experiments, to judge of the precise time at which the steel should be taken out. It is not meant to be understood that the temper indicated by a straw-color is that to which the steel plate, cylinder, or die, should be ultimately reduced, because it would then be found too hard, but merely that the temperature which would produce that color is that by which the peculiar sound would be occasioned, when the steel should be withdrawn from the water for the first time. Immediately on withdrawing it from the water, the steel plate, cylinder, or die, must be laid upon, or held over a fire, and heated uniformly until its temperature is raised to that degree at which tallow would be decomposed; or, in other words, until a smoke is perceived to arise from the surface of the steel plate, after having been rubbed with tallow: now the steel plate must then be again plunged into water, and kept there until the sound becomes somewhat weaker than before. It is then to be taken out and heated a second time, to the same degree, by the same rule of smoking tallow as before, and the third time plunged into water, till the sound becomes again weaker than the last; exposed the third time to the fire as before; and for the last time returned into the water and cooled. After it is cooled, clean the surface of the steel plate, cylinder, or die, by heating it over the fire. The temper must be finally reduced by bringing on a brown or such other lighter or darker shade of color as may best suit the quality of the steel for the purpose to which it is to be applied."

The following is another improvement of Mr. Jacob Perkins':—A cylinder of very soft or decarbonized steel is made to roll, under a great pressure, backward and forward on the hardened engraved plate, till the entire impression from the engraving is seen on the cylinder in alto-relievo. The cylinder is then hardened and made to roll again backward and forward on a copper or soft steel plate, whereby a perfect facsimile of the original is produced of equal sharpness.

The improved press, now generally used by steel and copper-plate printers, is also due to Mr. Perkins. In short, he bears the same relation to steel engraving that Senefelder does to the lithographic process.

Engraving on Stone, or Lithography—A modern invention, by means whereof impressions may be taken from drawings made on stone. The merit of this discovery belongs to Aloys Senefelder, a musical performer of the theatre at Munich about the year 1800. The following are the principles on which the art of lithography depends:—First, the facility with which calcareous stones imbibe water; second, the great disposition they have to adhere to resinous and oily substances; third, the affinity between each other of oily and resinous substances, and the power they possess of repelling water or a body moistened with water. Hence, when drawings are made on a polished surface of calcareous stone with a resinous or oily medium, they are so adhesive that nothing short of mechanical means can effect their separation from it, and whilst the other parts of the stone take up the water poured upon them, the resinous or oily parts repel it. Lastly, when over a stone prepared in this manner a colored oily or resinous substance is passed, it will adhere to the drawings made as above, and not to the watery parts of the stone. The ink and chalk used in lithography are of a saponaceous quality; the former is prepared in Germany from a compound of tallow soap, pure white wax, a small quantity of tallow, and a portion of lampblack, all boiled together, and when cool dissolved in distilled water. The chalk for the crayons used in drawing on the stone is a composition consisting of the ingredients above mentioned, but to it is added when boiling a small quantity of potash. After the drawing on the stone has been executed and is perfectly dry, a very weak solution of vitriolic acid is poured upon the stone, which not only takes up the alkali from the chalk or ink, as the case may be, leaving an insoluble substance behind it, but it lowers in a very small degree that part of the surface of the stone not drawn upon, and prepares it for absorbing water with greater freedom. Weak gum water is then applied to the stone, to close its pores and keep it moist. The stone is now washed with water, and the daubing ink applied with balls as in printing; after which it is passed in the usual way through the press, the process of watering and daubing being applied for every impression.

There is a mode of transferring drawings made with the chemical ink on paper prepared with a solution of size or gum tragacanth, which being *laid on the stone and passed through the press* leaves the drawing on the stone, and the process above described for preparing the stone and taking the impressions is carried into effect.

In Germany many engravings are made on stone with the burin, in the same way as on copper; but the very great inferiority of these to copper engravings makes it improbable that this method will ever come into general use.

Copper or steel plates may be transferred to stone and worked by power-presses; and from the lessened expense, it is now generally resorted to by publishers of maps where large quantities are required.

Perhaps one of the greatest advantages of the art of lithography is the extraordinary number of copies that may be taken from a block. As many as 70,000 copies or prints have been taken from one block, and the last of them nearly as good as the first. Expedition is also gained, inasmuch as a fifth more copies can be taken in the same time than from a copper-plate: and as regards economy, the advantage over every other species of engraving is very great.

Engraving on Silver and Gold.—M. Poitevin, a Frenchman, has succeeded in producing plates, engraved either in relief or in sunk lines, from which proofs may be taken. For the carrying out of this process from two to three hours only are required.

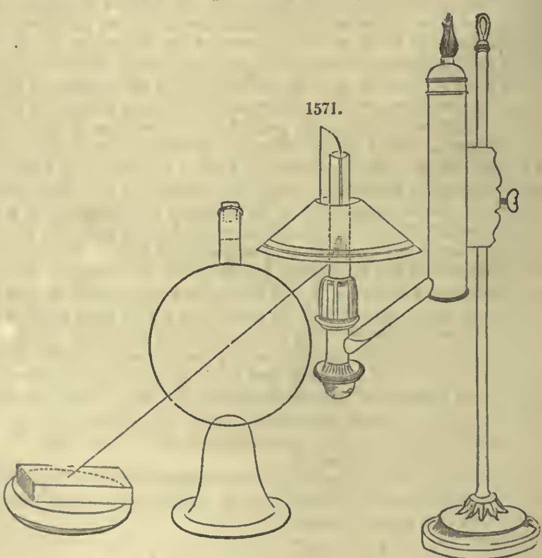
The engraving is first exposed to the vapor of iodine, which becomes deposited upon the black parts only. The iodized engraving is then applied, with slight pressure, to a plate of silver, or silvered copper, polished in the same manner as daguerreotype plates. The black parts of the engraving,

which have taken up the iodine, part with it to the silver, which is converted into an iodide at those parts opposite to the black parts of the design. The plate is then put in communication with the negative pole of a small battery, and immersed in a saturated solution of sulphate of copper, connected with the positive pole by means of a rod of platinum. The copper will only be deposited on the non-iodized parts, corresponding to the white parts of the engraving, of which a perfect representation will thus be obtained;—the copper representing the white parts, and the iodized silver the black parts. The plate must be allowed to remain in the bath for a very short time only; for, if left too long, the whole plate would become covered with copper. The plate, after having received the deposit of copper, must be carefully washed, and afterwards immersed in a solution of hyposulphite of soda, to dissolve the iodide of silver, which represents the black parts; it is then well washed in distilled water, and dried. The next operation is to heat a plate to a temperature sufficient to oxidize the surface of the copper, which successively assumes different tints, the heating being stopped when a dark brown color is obtained. It is then allowed to cool, and the exposed silver is amalgamated,—the plate being slightly heated, to facilitate the operation. As the mercury will not combine with the oxide of copper, a design is produced, of which the amalgamated parts represent the black, and the parts of the plate covered with oxide of copper represent the white parts. The amalgamation being complete, the plate is to be covered with three or four thicknesses of gold leaf; and the mercury is evaporated by heat, the gold only adhering to the black parts. The superfluous gold must then be cleaned off with the scratch-brush; after which the oxide of copper is dissolved by a solution of nitrate of silver, and the silver and copper underneath are attacked with dilute nitric acid. Those parts of the design which are protected by the gold, not being attacked, correspond to the black parts of the plate; the other parts corresponding to the white parts of the engraving, may be sunk to any required depth. When this operation is completed the plate is finished, and may be printed from in the ordinary method of printing from wood-cuts.

To obtain from the same prints plates with sunk lines similar to the ordinary engraved copper-plates, a plate of copper covered with gold is operated upon. On immersion in the sulphate of copper solution the parts corresponding to the white parts will become covered with copper. The iodine, or compound of iodine, formed, is then to be removed by the hyposulphite, the layer of deposited copper is oxidized, and the gold amalgamated, which may be removed by means of nitric acid,—the oxide of copper being dissolved at the same time. In this instance the original surface of the plate corresponds to the white parts of the print, and the sunk or engraved parts to the black parts, as in the ordinary copper-plate engravings.

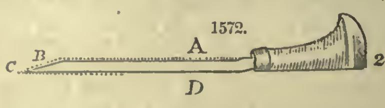
ENGRAVING ON WOOD. There are various modes for protecting the eyes when working by lamp-light, but we are aware of only one which both protects the eyes from the light and the face from the heat of the lamp. This consists in filling a large transparent glass globe with clear water, and placing it in such a manner between the lamp and the workmen that the light, after passing through the globe, may fall directly on the block, in the manner represented in the Fig. 1571. The height of the lamp can be regulated according to the engraver's convenience, in consequence of its being movable on the upright piece of iron or other metal which forms its support. The dotted line shows the direction of the light when the lamp is elevated to the height here seen; by lowering the lamp a little more, the dotted line would incline more to a horizontal direction, and enable the engraver to sit at a greater distance. By the use of these globes one lamp will suffice for three or four persons, and each person have a clearer and cooler light than if he had a lamp without a globe solely to himself.

1571.



There are only four kinds of cutting tools* necessary in wood engraving, namely: gravers, tint-tools, gouges or scoopers, and flat tools or chisels. Of each of these four kinds there are various sizes. Fig. 1572 shows the form of a graver that is principally used for outlining or separating one figure from another. A is the back of the tool; B the face; C the point; and D what is technically called the belly. The horizontal dotted line C, 2, shows the surface of the block, and the manner in which part of the handle is cut off after the blade is inserted.† This tool is very fine at the point, as the line which it cuts

1572.



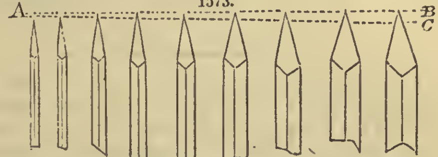
* A sharp-edged scraper, in shape something like a copper-plate engraver's burnisher, is used in the process of *lowering*.

† The handle, when received from the turner's, is perfectly circular at the rounded end; but after the blade is inserted a segment is cut off at the lower part, as seen in Fig. 1572.

ought to be so fine as not to be distinctly perceptible when the cut is printed, as the intention is merely to form a termination or boundary to a series of lines running in another direction. Though it is necessary that the point should be very fine, yet the blade ought not to be too thin, for then, instead of cutting out a piece of the wood, the tool will merely make a delicate opening, which would be likely to close as soon as the block should be exposed to the action of the press. When the outline tool becomes too thin at the point the lower part should be rubbed on a hone, in order to reduce the extreme fineness.

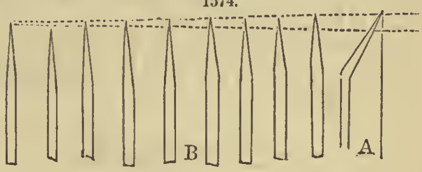
About eight or nine gravers of different sizes, beginning from the outline tool, are generally sufficient. The blades differ little in shape, when first made, from those used by copper-plate engravers; but in order to render them fit for the purpose of wood engraving, it is necessary to give the points their peculiar form by rubbing them on a Turkey stone. In Fig. 1573 are shown the faces and part of the backs of nine gravers of different sizes; the lower dotted line A C shows the extent to which the points of such tools are sometimes ground down by the engraver in order to render them broader. When thus ground down the points are slightly rounded, and do not remain straight as if cut off by the dotted line A C. These tools are used for nearly all kinds of work, except for series of parallel lines, technically called "tints." The width of the line cut out, according to the thickness of the graver towards the point, is regulated by the pressure of the engraver's hand.

1573.



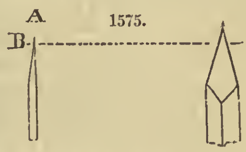
Tint tools are chiefly used to cut parallel lines forming an even and uniform *tint*, such as is usually seen in the representation of a clear sky in wood-cuts. They are thinner at the back, but deeper at the side than gravers, and the angle of the face, at the point, is much more acute. About seven or eight, of different degrees of fineness, are generally sufficient. Fig. 1574 will afford an idea of the shape of the blades towards the point. The handle of the tint tool is of the same form as that of a graver. The figure marked A presents a side view of the blade; the others marked B show the faces. Some engravers never use a tint tool, but cut all their lines with a graver. There is, however, great uncertainty in cutting a series of parallel lines in this manner, as the least inclination of the hand to one side will cause the graver to increase the width of the white line *cut out*, and undercut the raised one *left*, more than if in the same circumstances a tint tool were used. This will be rendered more evident by a comparison of the points and faces of the two different tools, Fig. 1575.

1574.



The tint tool, being very little thicker at B than at the point A, will cause a very trifling difference in the width of a line in the event of a wrong inclination, when compared with the inequality occasioned by the unsteady direction of a graver, whose angle at the point is much greater than that of a proper tint tool. Tint tools ought to be sufficiently strong at the back to prevent their bending in the middle of the blade when used, for with a weak tool of this kind the engraver cannot properly guide the point, and hence freedom of execution is lost. Tint tools that are rather thick in the back are to be preferred to such as are thin, not only from their allowing of great steadiness in cutting, but from their leaving the raised lines thicker at the bottom, and consequently more capable of sustaining the action of the press. A tint tool that is of the same thickness both at the back and the lower part, cuts out the lines in such a manner that a section of them appears as in Fig. 1576: the black raised lines from which the impression is obtained being no thicker at their base than at the surface; while a section of the lines cut by a tool that is thicker at the back than at the lower part appears as in Fig. 1577. It is evident that lines of this kind having a better support at the base, are much less liable than the former to be broken in printing.

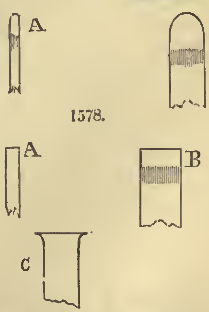
1575.



1576.

1577.

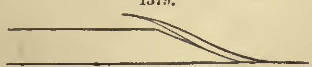
Gouges of different sizes, Fig. 1578, from A the smallest to B the largest, as here represented, are used for scooping out the wood towards the centre of the block; while flat tools or chisels, of various sizes, are chiefly employed in cutting away the wood towards the edges. Flat tools of the shape seen in figure C are sometimes offered for sale by tool-makers, but they ought never to be used; for the projecting corners are very apt to cut under a line, and thus remove it entirely, causing great trouble to replace it by inserting new pieces of wood.



1578.

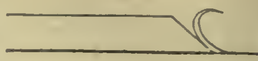
The face of both gravers and tint tools ought to be kept rather long than short; though if the point be ground *too fine*, it will be very liable to break. When, as in Fig. 1579, the face is long—or, strictly speaking, when the angle, formed by the plane of the face and the lower line of the blade, is comparatively acute—a line is cut with much greater clearness than when the face is comparatively obtuse, and the small shaving cut out turns gently over towards the hand. When, however, the face of the tool approaches to the shape seen in Fig. 1580, the reverse happens; the small shaving is rather

1579.

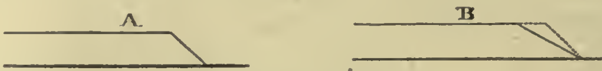


ploughed out than cleanly cut out; and the force necessary to push the tool forward frequently causes small pieces to fly out at each side of the hollowed line, more especially if the wood be dry. The shaving also, instead of turning aside over the face of the tool, turns over before the point, as in Fig. 1580, and hinders the engraver from seeing that part of the pencilled line which is directly under it. A short-faced tool of itself prevents the engraver from distinctly seeing the point. When the face of a tool has become obtuse, it ought to be ground to a proper form; for instance, from the shape of the figure A to that of B, Fig. 1581.

1580.



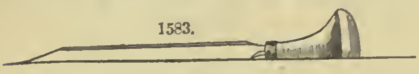
1581.



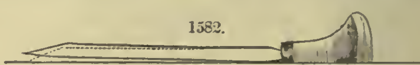
Gravers and tint tools when first received from the maker are generally too hard,—a defect which is soon discovered by the point breaking off short as soon as it enters the wood. To remedy this, the blade of the tool ought to be placed with its flat side above a piece of iron—a poker will do very well—nearly red-hot. Directly it changes to a straw-color it is to be taken off the iron, and either dipped in sweet oil or allowed to cool gradually. If removed from the iron while it is still of a straw-color, it will have been softened no more than sufficient; but should it have acquired a purple tinge, it will have been softened too much; and instead of breaking at the point, as before, it will bend. A small grindstone is of great service in grinding down the faces of tools that have become obtuse. A Turkey stone, though the operation requires more time, is however a very good substitute, as, besides reducing the face, the tool receives a point at the same time. Though some engravers use only a Turkey stone for sharpening their tools, yet a hone in addition is of great advantage. A graver that has received a final polish on a hone cuts a clearer line than one which has only been sharpened on a Turkey stone; it also cuts more pleasantly, gliding smoothly through the wood, if it be of good quality, without stirring a particle on each side of the line.

The gravers and tint tools used for engraving on a plane surface are straight at the point, as are here represented, Figs. 1582 and 1583; but for engraving on a block rendered concave in certain points by lowering, it is necessary that the point should have a slight inclination upwards, as in Fig. 1582. The dotted lines show the direction of the point used for plane-surface engraving. There is no difficulty in getting a tool to descend on one side of a part hollowed out or lowered; but unless the point be slightly inclined upwards, as is here shown, it is extremely difficult to make it ascend on the side opposite, without getting *too much hold*, and thus producing a wider white line than was intended.

1583.

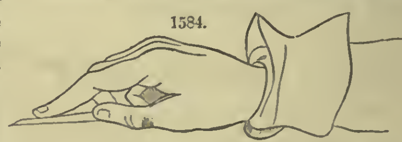


1582.

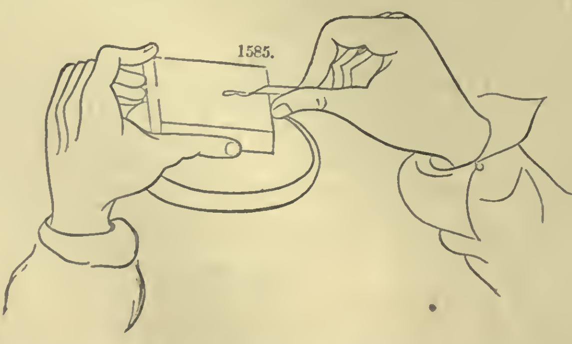


As the proper manner of holding the graver is one of the first things that a young wood-engraver is taught, it is necessary to say a few words on the subject. Engravers on copper and steel, who have much harder substances than wood to cut, hold the graver with the fore-finger extended on the blade beyond the thumb, Fig. 1584, so that by its pressure the point may be pressed into the plate. As box-wood, however, is much softer than copper or steel, and as it is seldom of perfectly equal hardness throughout, it is necessary to hold the graver in a different manner, and employ the thumb at once as a stay or rest for the blade, and as a check upon the force exerted by the palm of the hand, the motion being chiefly directed by the fore-finger, as is shown in Fig. 1585.

1584.

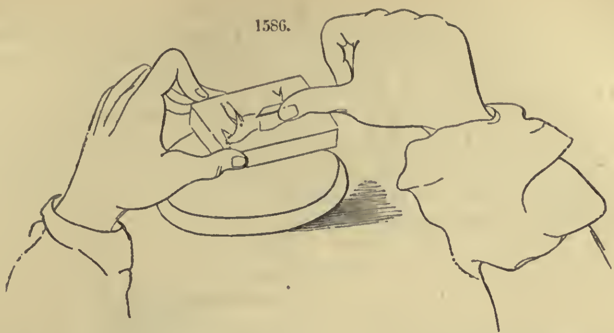


1585.



The thumb, with the end resting against the side of the block, in the manner above represented, allows the blade to move back and forward with a slight degree of pressure against it, and in case of a slip it is ever ready to check the graver's progress. This mode of resting the thumb against the edge

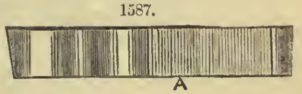
1586.



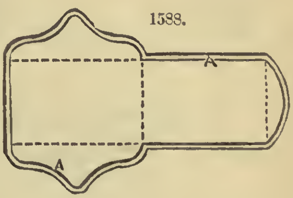
of the block is, however, only applicable when the cuts are so small as to allow of the graver, when thus guided and controlled, to reach every part of the subject. When the cut is too large to admit of this, the thumb then rests upon the surface of the block, as seen in Fig. 1586; still forming a stay to the blade of the graver, and a check to its slip, as before.

ENVELOP MACHINERY, by M. Rémond. In earliest stages of the invention, the paper blanks were cut out, and the subsequent folding performed entirely by hand; but the necessity of a prodigious increase in the power of production, speedily led to the employment of mechanical means for the entire manufacture. One of the first of these improvements was an improved paper-cutting machine, a plan for cutting out the blanks. Many envelop-makers use this machine now; but others employ a hollow cutting die, cutting through about 250 sheets of paper at once; but the cutter being made very thin, to give an easy cut, generally springs under pressure, and the blanks thus become unequal in size, easily detected when the folding operation comes into action.

1587.



1588.



As an example of the class of cutting-die employed, we have engraved two views of it. Fig. 1587 is a sectional elevation of the die, and Fig. 1588 a plan. It is simply a knife, shaped to the contour of the envelop blank, A being the sharp edge. This is forced through a thick pile of sheets by a convenient press, so as to produce blanks agreeing in shape to the interior of the two lines in Fig. 1588. This shape, it will be observed, is not one now in common use, but it serves as an example of some of the attempts which have been made to give additional security, and probably a greater appearance of style. The cut pieces are gummed on one side, at the ends of each flap; and when folded, as indicated by the dotted lines in the plan of the cutter, the long narrow part adheres to one end of its counterpart, forming the back, and the remaining pair of flaps fold down upon it. This shape of envelop has, for many reasons, never come into ordinary use.

In 1845 a folding machine for completing the envelops from the blanks was invented by Mr. Edwin Hill, and Mr. Warren De la Rue, jointly, and is now worked in the extensive establishment of Messrs. De la Rue, London. Its rate of production is stated to be 42 folded envelops per minute; or, for a day's work of 10 hours, 25,200. The blanks are laid by hand upon a table carrying a metal frame, the interior of which exactly corresponds to the size and shape of the finished envelop; and immediately over this is a box or plunger, which, fitting to the interior of the frame, is caused to descend upon the paper blank when laid over it, thus creasing it on all the four sides, as will be understood on examining a partially-opened envelop; the box then opens to admit of a partial folding. In this condition the blank has simply been creased, and the four flaps stand up at right angles to the plane of the sheet. Before the creasing box is entirely raised, two of a set of folders, placed one on each of the four sides of the frame, come forward and press down the two flaps corresponding to their situation; and the remaining pair of folders come into action to press their two flaps after the other portion of the plunger is raised. These movements complete the envelop, by turning down the right angle flaps to the plane of the sheet, and the next step is to remove them from the folding frame. For this purpose two finger-shaped projections of caoutchouc are made use of; and, owing to the strong adhesion existing between this substance and paper, the folded envelops are quickly removed as fast as they are produced. The twenty-two movements required in folding each envelop are performed rapidly and noiselessly, principally by various adaptations of cams. Prior to Messrs. Hill and De la Rue's invention, the only facilitation of manual labor in folding was obtained by the use of a species of tool, which partially creased the blanks, leaving them to be turned up and finished by hand. Compared with "the results of machinery," the hand labor, although in itself an astonishing instance of practical dexterity, is inordinately slow. Girls are always employed in this work; and a first-rate hand can fold and gum for use from 3,000 to 3,500 per day, or from 5 to 6 per minute, the average performance being from 2,500 to 3,000. To arrive at this perfection, at least six or eight months' practice are required.

By another comparative statement now before us, we find that, in unstamped envelops, hand labor, 6 per minute, 10 hours per day = 3,600; the work of one girl. Stamped envelops, hand labor, 4 1-6 per minute, 10 hours per day = 2,500, a day's work; the time being divided into 7 hours for folding and gumming, and 3 for stamping

Figs. 1589 to 1597 exhibit, in very full detail, an improved folding machine, patented during the present year, by M. Rémond. In this machine some ingenious appliances are introduced, whereby atmospheric pressure is employed to facilitate the feeding in of the blanks to the folding apparatus and the secondary folding action of the flaps in connection with the creasing plunger.

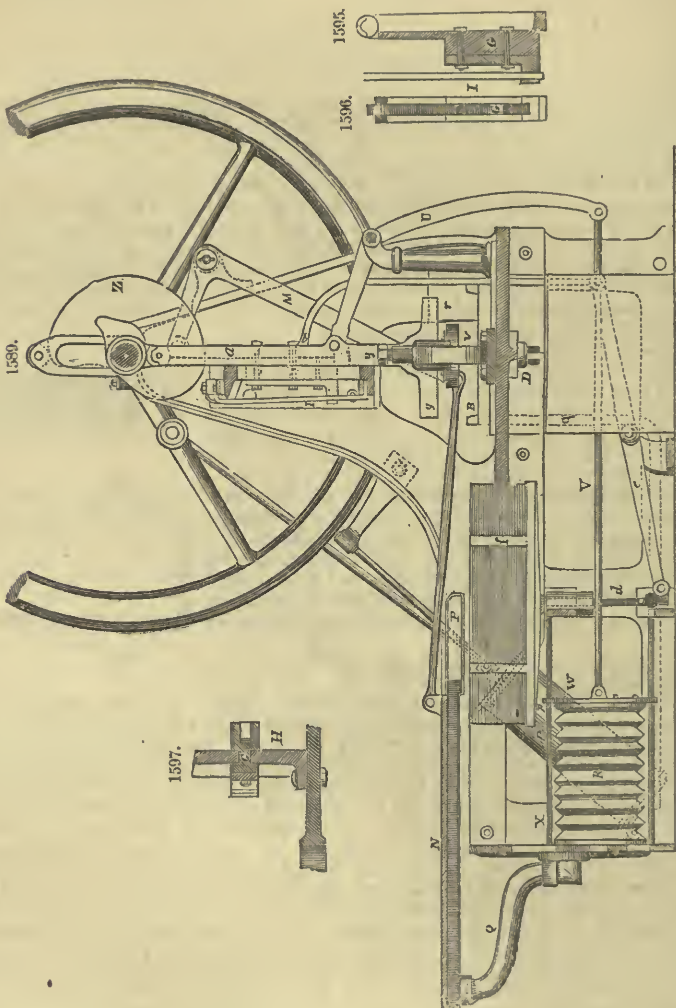
Fig. 1589 is a side elevation of the machine, partially in section. Fig. 1590 is a corresponding view at right angles to Fig. 1589. Fig. 1591 is a vertical section of a portion of the machinery, taken at the dotted line A B in Fig. 1589. Fig. 1592 is a horizontal view or plan of the folding table, with the details of the apparatus for receiving the blanks preparatory to folding. Fig. 1593 is a transverse section, taken at the dotted line C D in Fig. 1589. Fig. 1594 is a plan of the feeding-slide N N in Figs. 1589 and 1590. Figs. 1595, 1596, and 1597 are details of the guide apparatus for the several movements on the main shaft A of the machine.

1595.

1596.

1589.

1597.



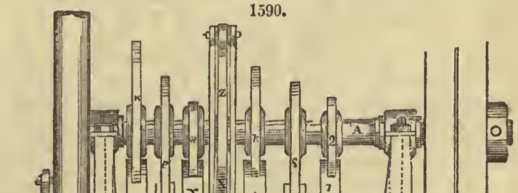
The arrangement of the mechanism is such, that a quantity of blanks of the required size being placed on the feeding table, each will be taken up singly from the pile, and fed into the folding apparatus by means of an instrument, in which, at proper intervals, a partial vacuum is formed, whereby each sheet is sucked up against the surface of the fingers for conveyance to the folder.

The first step of the process of folding is accomplished similarly to the mode hitherto adopted, and generally explained, in reference to Messrs. De la Rue's machine, that is, the flaps of the blanks are bent to a right angle by the same means; but a novel arrangement is introduced for the performance of the secondary fold. The bottom of the creasing frame or box is perforated, so that the passing back of the plunger leaves the blank within the recess, with its four flaps standing upright; and here the second application of the atmospheric action comes into play, for the purpose of giving the flaps a pre-

liminary inclination inwards, in order to fit them for receiving the flat folding pressure of the return stroke of the plunger. To this end the sides of the folding box are perforated, so as to allow streams of atmospheric air to be forced against the outsides of the flaps; so that, on the descent of the plunger, they will all be folded down at once, the interior and under surface of the plunger being suitably formed to cause the flaps to succeed each other in their proper order. In addition to this, certain contrivances are adapted for stamping the outer flaps with an embossed or perforated device, and also for gumming the lowest flap as a fastening for the completed envelop.

A is the main driving shaft, which gives motion to the machine. It carries at one end a fast-and-loose driving pulley, and at the other a fly-wheel, to assist in regulating the movement; and its intermediate portion is fitted with seven cams, for communicating motion to the different working parts. B is the folding box, or recess, in which the folding process is performed. It consists of four side pieces, at the angles of which are projections C C, between which the blanks are successively fed, so that they may be correctly placed, and held during the action of the plunger. D is the door or movable bottom of the box, hinged at one end, so that when an envelop has been folded in the box, it may be discharged below; it is perforated with numerous holes for the escape of the air, as the blank is forced down, and is kept closed by means of a lever E, which is actuated at the proper intervals of time by means of the cam F on the main shaft, giving motion to a slide G, of which there are seven, all alike in construction, in connection with the same number of cams. The slide works between two fixed guiding surfaces H H, as detailed in Figs. 1595 and 1596, and has at its upper end a small anti-friction roller, kept up in contact with its actuating cam by the elastic tension of a band of vulcanized India-rubber. The lower end of the slide presses on the tail of the cranked lever E, the other end of which rests against the under surface of the movable door D, so that the latter is kept closed during the proper portion of the revolution of the main shaft. The feeding action is accomplished by the exterior cam K on the shaft, giving motion—as before explained with regard to the cam F—to its slide L, which is attached to the shorter arm of the cranked lever M, the opposite arm of which is jointed by connecting rods to the feeder N. This instrument is carried upon a slide, having dovetailed edges, moving between fixed guiding dovetails at O O. It consists of two hollow fingers P P, each having an opening on the under side; the interior of the fingers opening into the hollow portion of the slide, shown by dotted lines, allowing of a partial vacuum being obtained within the fingers when the exhaust movement comes into use. A flexible tube Q, of vulcanized India-rubber, is attached to the under side of the slide, the opposite end being connected with the bellows R, which receive motion at the required intervals from the cam S acting on the slide T in connection with the bent lever U, carried by a pillar at the back of the machine. The longer end of this lever is jointed by a connecting rod V to the front plate W of the horizontal bellows running on guide spindles X X. In this way, when the under side of the fingers comes upon the top of the pile of blanks at Y, the exhausting action is brought into play, and the top sheet is carried over to the top of the box B for deposit, with its angles fitting the corner guide pieces, as in plan at Fig. 1592. At the termination of the outward stroke of the bellows, the sheet is separated from them by the action of a valve in the bellows, opening outward at the commencement of the return stroke. The platform Y carrying the pile of blanks, is made to rise and fall to suit the feeding action, by a mechanical arrangement worked from the cam Z. This cam actuates a slide a, from which an arm b descends for connection with the long lever c at the bottom of the framing, the opposite end of which is jointed to a projection on the vertical spindle d of the platform. To compensate for the continual decrease in the height of the pile of blanks, so that the upper one may always come in contact with the lifting fingers when the platform rises, an India-rubber spring e is added, its action being to keep up the platform in contact with the fingers, when permitted to do so by the actuating cam. As every thing depends upon accuracy of set, it becomes of the first importance to place the blanks in the exact position intended; and to facilitate this, four projecting arms, or guides $f f$, are formed on the top of the platform, agreeing, as in the angle pieces of the folding box, with the angles of the flat blanks.

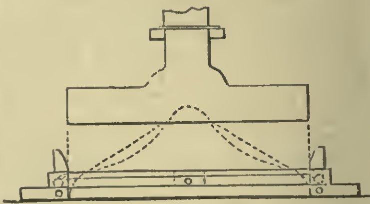
1590.



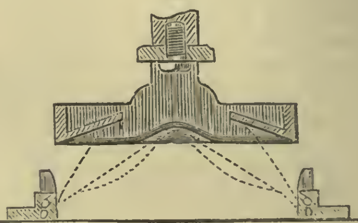
As the blanks are fed into proper position, the folding plunger g comes into action. This is a hollow rectangular metal frame, carried by a slide h, receiving motion from the cam k. It has in its interior a set of three projections, which, in the secondary movement, act on the separate flaps, folding them all

down at once, when they are held in the required inclined position by the atmospheric side currents as previously detailed. The inclined projections are essentially necessary, in order that the flaps may be folded down in their proper relative positions; the projection l pressing on one of the side flaps, causes it to be folded first; afterwards the projection m acts upon one of the ends, whilst the third, n, carries down the opposite one, the final folding being completed by the under edges of the plunger, which gives a sharp pressure to the initiatory fold of the whole series. By suitably setting these projections, any order may be given to the flaps—thus, if the two end ones do not overlap each other, they may be folded down together by equal projections. The detailed figures, 1598 and 1599, exhibit two intermediate stages of the plunger's folding action. Fig. 1598 is a longitudinal elevation of the plunger and the top of the folding box in the position taken up after the first action of the former, the side air passages for inclining the flaps being at *o o o*. Fig. 1599 is a longitudinal section of the same parts, taken just as the plunger is about to descend in its secondary movement to give the completing fold.

1598.

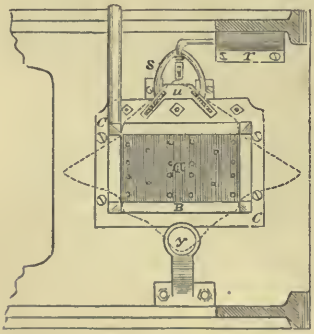


1599.

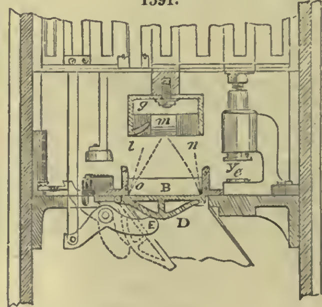


The necessary atmospheric side pressure on the flaps is obtained from the inclined air-pump p, the piston of which is driven by a crank pin on the fly-wheel; and a tube q conveys the forced air from the bottom of the pump to a hollow channel passing all round the edges of the folding box, as dotted in the plan, Fig. 1592, whence the orifices already pointed out, open inwards to the box. For the application of gum, or other cementing fluid, to the lowest flap, to secure the three stationary ones, a fountain is placed at r, from the bottom of which two tubes $s\,s$ branch out to the two flat tubular receptacles $t\,t$ inclosed in a vessel u, the supply being regulated by a stop-cock before the junction of the two supply branches. The gumming action is performed by pieces of sponge placed in the upper ends of the flat tubes t, which, standing slightly above their upper edges, the presser v descending just before the plunger, presses the edges of the lowest flap upon the sponge, as clearly illustrated in the plan view. This presser receives its motion from the cam w acting on the slide x, to which the presser is attached. If it is intended to stamp or emboss the outer flap with an embossed or perforated device, dies are applied as at $y\,z$. The die y being attached to a slide 1, acted on by the external cam 2, the stamping action takes place just before the descent of the plunger.

1592.



1591.

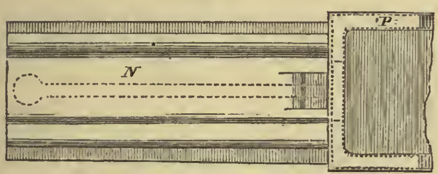


This machine produces easily 60 envelops per minute, or 36,000 per day, completed, gummed, and stamped, and might probably be worked faster. As at present practised in other modes of production, the folding, gumming, and stamping are all separate processes; and as, at each of these operations, every single envelop must be separately handled, we may form a tolerable conception of the economy gained by the use of M. Rémond's machine, as the most improved contrivance of earlier date saves no more than one-third of the manual labor. The isolation of the different stages of manufacture, consequent upon the employment of manual labor, adds immensely to the cost of production, the loss mainly arising from the mere removals from one process to another. In hand-stamping, a child will perhaps get through 8,000 or 9,000 per day; and then there must be an assistant to turn the tops where the stamp has been placed, and count them into parcels.

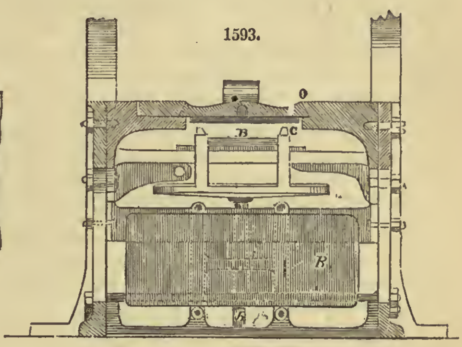
Since the first anticipations of the value of the envelop for general consumption, many modifications have been introduced. In 1844, Mr. Wilson, the inventor of the cutting machine, hit upon the ingeniously simple mode of economizing the paper in cutting out the blanks, by cutting the original web of paper diagonally across its width. Formerly, when the web was divided longitudinally, and then by transverse cuts at right angles, the rectangular sheet thus formed, when cut up into diamond pieces for

envelops, suffered considerable loss in the reduction. By Mr. Wilson's plan this was avoided, as the transverse cuts being all made diagonally, each blank fitted exactly to its neighbor, and this source of loss was removed. In 1846, again, Mr. Charles Chinnock obtained a patent for some contrivances for the obtainment of greater security of enclosure, by applying the ordinary postage stamp, or other adhesive labels, so as to become a fastener for the edges of the paper forming the envelop. In one of his arrangements, a small hole, somewhat less than the area of a postage stamp, is punched at the right-hand corner of the address side, so that, when the stamp is put on, it adheres not only to the edges of the hole, but also to the turned-in edge produced in the end fold of the envelop, as well as partially to the enclosed note. Thus the enclosure cannot be removed without leaving detective marks. According to another mode, the patentee punches holes of various sizes through the parts of the envelop where the seal is placed—in some cases placing a bit of blotting-paper beneath, this being for the purpose of securing the whole by the seal. In another arrangement, the envelop is the same shape as that now generally used, having four triangular flaps, meeting in the centre for the seal. In the ends of three of these flaps are small holes, each one a little different in size, so that when folded the smallest hole is the lowest, and the largest the third in the layers, whilst the fourth is blank, the wax below which not only secures all the flaps, but adheres also to the enclosure. When a piece of blotting-paper is placed below the holes, as in another modification, any attempt to open the letter would involve a tear.

1594.



1593.



The ordinary four-cornered envelop, fitted to form what M. Rémond calls the "Detector," appears to answer all the requisites of security and elegance. The sealing-flap is embossed with some device, the centre of which is perforated in any ornamental way, and a colored wafer is placed beneath it, showing through the perforations like a colored device. When this is fastened in the usual way, a very slight examination serves to show whether or not it has been tampered with. If the wafer is used, and hot water or steam has been employed to soften it, its brilliancy will have entirely disappeared; and if attempted to be cut through, its substance is so thin, that, either wet or dry, the chances are, that the minute integuments of the star, or other device, will be broken or disarranged. This species of seal is besides ornamental, and for general purposes may supersede the now common plan of color-stamping.

The only American machine in practical use is one secretly used by Bell & Gould, Nassau-street, N. Y. We are unable to give any details respecting it.

ETCHING. The entire apparatus is contained in a box not larger than a music-book. They consist of copper-plates, &c., etching-needles, hand-rest, etching-ground, dabber, oil-rubber, rottenstone, smoking-taper, engraver's-shade, bordering-wax, stopping-out varnish, tracing-paper, aquafortis, &c.

Ground.—The ground is composed of asphaltum, Burgundy-pitch, and beeswax. Take equal portions of the above-named materials, place them in an earthen pipkin in an oven, and melt them. The mass must be kept stirred until well incorporated; any small piece of wood will answer this purpose. When well mixed, it must be poured into a basin of cold water, and when nearly cold should be pressed and rolled with the hand, that all the water may be discharged, then made into a ball. Procure a piece of worn silk, but be careful it is without holes, double it, place the ball therein, and tie up the ends with packthread, taking care that the double silk reaches well over the ball. When tied tight, cut off the overplus silk, and let the knot remain for a hand-hold. Be sure that the silk is tight over the ball.

Dabber.—Take another piece of silk, twice the size of the last, double it, place in it a ball of coarse wool well picked out, about the size of a small apple, tie it up in the same way as the ball for the ground, and it is ready for use.

Oil-rubber.—The next thing necessary is an oil-rubber, which is simply a strip of woollen cloth, about two inches wide, rolled up tight, and bound over with packthread or thin tape. With a sharp knife cut off one end, avoiding the string, so that the surface may be quite flat. This is used for taking out stains or polishing the plate.

Rottenstone.—Procure a piece of fine flannel, rather less than the silk which covers the etching ground ball, double it, place on it a small quantity of rottenstone in powder, which tie up in a bag. A small portion of fine whitening in the lump should be kept at hand for the sake of cleanliness: any small box will answer this purpose.

Smoking-taper.—Procure a wax taper; uncoil it by degrees before the fire until it is all equally pliant: double it up in about six lengths, give it one twist while warm, and turn it a few times before

the fire, that the pieces of taper may adhere to each other; melt the wax at one end, so that the wick is exposed; see that all the cotton ends will light freely: care should be taken to extinguish the cotton, or it will revive with the least draught, and may become dangerous.

Bordering-wax.—This may be obtained ready made, but engravers make it to their own liking. The component parts are three ounces of resin, two ounces of beeswax, and such a quantity of sweet-oil as will soften the mixture to your fancy. Procure an earthen pipkin, place in the bottom a small quantity of sweet oil, (half an ounce or more,) add your resin and beeswax, broken in small pieces; when melted, work the ingredients well together with a stick until thoroughly incorporated, then pour into a basin of cold water; as it gets cold, work it well with the hands by pulling out into lengths and doubling it together again: the more it is worked the better it will be for use. Should it turn out brittle, return it broken to the pipkin, and add more oil; work it well together as before; pour it into water, and work it again with your hands.

Engraver's-shade.—The next thing required is a shade, which can be made of wire. Bend it to a half-circle, bind it together with waxed string, lay it on tissue paper, cut away all but half an inch round the wire, cover that half inch with paste, and turn it over the wire; when dry, the shade is complete. Fasten a light string to the centre of the half-circle, and suspend it from the window-latch when in use. This shade must be placed in a forward position, sloping before your plate, and the white light it produces will enable you to see the lines made by your etching-needle. It is now the real amusement begins. You can work any time you please at the plate, and lay aside without injury to it.

Hand-rest.—Any flat and thin piece of wood will answer this purpose, which is merely to keep the hand clear of the plate whilst at work.

Stopping-out Varnish.—Turpentine varnish is superior, for several reasons, to Brunswick black.

Turpentine Varnish.—Break small bits of resin into a vial, cover it over with spirits of turpentine to about twice the height of the resin. Place the bottle in a small saucepan of water on the hob, near enough to the fire to make and keep the water hot; a cork may be lightly placed in the mouth of the bottle, as the mixture will require to be shaken occasionally.

A small portion of this mixture should be poured into a small pot, with a little lampblack added, to give it color, and well incorporated. This last is necessary to prevent lumps; it may be done by working the mixture well together with the camel-hair pencil. You have now a good stopping-out varnish. With this varnish go over the border or margin of your plate: do this when about to put it away, and the varnish will become hard by being left a night to set.

When inclined to put your plate through the process of biting-in, again go over the margin, using the same brush and mixture. You can always work it up by adding a little turpentine. When it is set so hard that you can place the finger on it without adherence, it is time to make up your wall or border of wax to hold the aquafortis.

Aquafortis.—Provide yourself with three half-pint bottles having glass stoppers, and two pint earthen jugs with spouts. Then obtain at the chemist's half a pound of nitric acid in a bottle No. 1 Pour into bottle No. 2 rather less than the fourth of the nitre; pour the bottle three parts full of water; with a slow action pass it into one of your pint jugs, and back again to the bottle, to unite it well. In bottle No. 3 put one half of the remaining nitre; water it as before; see that the nitric acid in bottle No. 1 is well stoppered, and cover it with a piece of old glove.

Tracing, and Tracing-paper.—Tracing-paper of various qualities may be purchased at any depôt of arts. But, in case of necessity, very good tracing-paper may be made by saturating with a camel-hair pencil the finest tissue paper with the following mixture:—Half an ounce of the balsam of Canada to one ounce of the spirits of turpentine, shaken well together in a two-ounce bottle: it requires no heat. When covered with the mixture, hang the paper on a line to dry: then wash in like manner the other side.

Place your drawing on the tracing-board, (a piece of soft planed deal,) over it lay the tracing-paper, fasten down with the brass-headed points, not through the drawing, but close to it, so that the pressure of the brass head secures both the drawing and tracing-paper from moving. Go carefully over all the lines of your drawing with an H-pencil, occasionally placing a piece of white paper between the drawing and the tracing-paper, to ascertain that you have not neglected any part of the lines on the drawing.

Transferring-paper.—This is very easily made, as follows:—Take half a sheet of very fine bank post paper, lay it on a clean place and rub it well with the scrapings of red chalk; a small bit of sponge is good for this purpose. Apply the chalk until the paper is all of one color, then, with a piece of clean old muslin, rub the greater part of the color from the surface. The color may be renewed occasionally as the marking becomes faint.

Testing the Ground.—Heat one corner of your plate, and rub over it *the ground*, in a thin and even surface. Next apply your dabber, to make a yet more equal distribution of the ground. When cold, mark over it with rather a blunt needle, (No. 3.) Should the ground be brittle, and crack with the passage of the needle, add to it more beeswax; should it drag with the needle, more asphaltum: the ground will easily melt again. When a ball is made to your satisfaction it will last a long time. The weather has considerable effect on the mixture, but the quality of the ingredients more, so that it is advisable to get the ground as perfect as you can while you have the melting-pot in use.

Heating the plate for ground.—You must have a small hand-vice with a haft of wood to resist the passage of heat to the hand. If your plate is stained or discolored, the mark must be removed with the oil-rubber, with a little rottenstone and oil, polished off with a bit of old muslin powdered with whitening. Be careful that no dust remains on the plate. Screw the vice on the long side of your copper-plate with a slight hold, covering the part grasped by the jaws of the vice with a small piece of paper, to prevent injury to the surface.

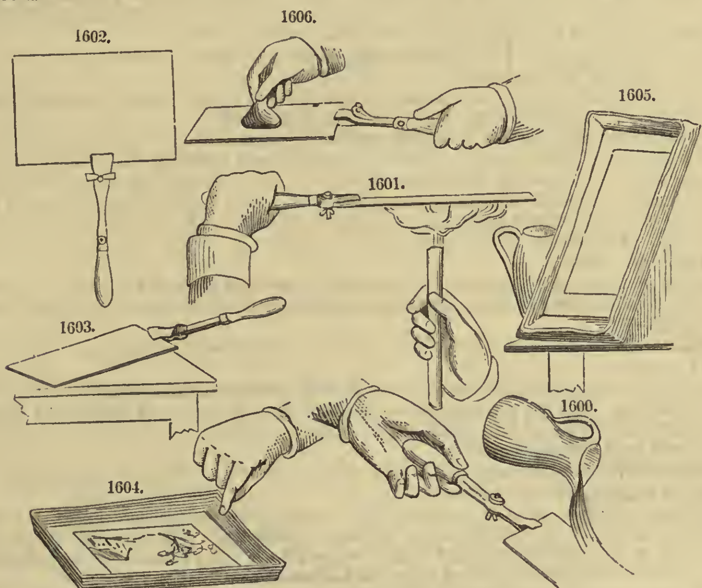
Heating may be performed by burning paper under the back of the plate; but a stove or clear fire

is much the preferable mode. Be careful not to overheat your plate. If the surface becomes discolored the plate is over hot: as a test, turn it over and spit on the back; if the moisture jumps off, the plate is sufficiently hot: should it hiss and remain on the plate, more heat must be obtained.

A piece of sailcloth, rather larger than the plate, should be warmed by laying it before the fire during the heating process; place it on the table, and lay upon it the plate, retaining the vice. Now pass your ball of ground over it backwards and forwards until the plate is covered, spreading the ground *as evenly and thinly as possible.* Then use your dabber with a quick action, pressing it down and plucking it up. If the ground does not distribute itself easily burn paper under it, as before, until it shines all over, being cautious that the ashes of the paper do not settle on the surface; dab on again, decreasing the pressure but not the speed of action, until the surface is all over alike.

Smoking the plate.—Have your taper ready, and a single taper or candle to take the light from; the surface of your plate being perfectly covered, it may be as well to renew the heat in your plate by a paper burnt under the back until the surface shines, taking the same precautions as before.

Hold the plate up in your left hand, with the face downward; light your smoking-taper, at the same time, having all the wicks burning, pass it rather quickly round the margin, and by degrees towards the centre, using a fluttering action with the hand; smoke on until the whole surface is of a dark color, keeping the taper at such a distance from the plate that the burning cotton may have no chance of touching it, although the flame spreads over it: when the surface is all black alike, and no sooty marks are to be seen on the working part of the plate, the ground is fit for use. Take the plate, face downward, to some convenient place, and pour cold water over the back, holding the plate in a sloping position, the vice up, Fig. 1600. This last process produces a stronger and harder surface than could be obtained if the plate were left gradually to cool. Now place the plate face downwards, supported on one side by the screw of the vice, Fig. 1601. Clean the smoke from the back, and let it remain until quite cold.



As Figs. 1600 to 1611 consist of examples of the etching, biting-in with the acid, &c., I shall take advantage of it to exemplify the manual craft of laying the ground, smoking, &c. Some difficulty may be found in laying the first ground with success; but having managed one well, you may be sure for the future.

Transferring.—If you have not an etching-board place your copper-plate on a thick piece of brown paper, larger than the plate; make two ribs of the same paper, doubled four or more times, and about an inch wide; place them at each end of your plate on the brown paper, and fasten them with sealing-wax: these ribs serve as shoulders for *the rest* to lay on, which will prevent your hand from touching the work.

You may now cut your tracing-paper to the size of your plate, having ruled your margin line, if one is required. Place your tracing reversed, that is, the pencil side to the plate. Fix it with bits of soft wax round the border, leaving open the bottom to admit the transferring-paper, which introduces the chalk side next to the plate: the upper side of the paper must be kept clean, that you may see the pencil lines on your tracing-paper. Next with an H H pencil, *sharp and short in the cut,* go over all the lines of your tracing with rather an upright hand, that you may be able to make strong pressure: the upper side of your tracing-paper, not being marked with pencil, will show whether you have gone over the whole of the lines with the pencil on the upper side; look sideways at your work, and the black-lead mark will be perceptible. Before you advance far in your transfer, lift up the bottom of your tracing to ascertain if the lines are of sufficient strength; if not, apply more red chalk to your transfer-paper. When you think the transfer is completed, do not take off the whole of your paper,

but allow the part affixed by the top spots of wax to remain. You can then lift up the whole of the work, and if any part of it has been neglected the tracing can again be laid down, and the omission rectified.

Etching.—You must begin with needle No. 1 (the fine point) and go carefully over the outline, not making much impression on the copper, but sufficient to remove the ground; with the same point go over all the lighter parts, increasing the pressure, so that a slight indentation may be made on the plate.

No. 2 point may now be used to go over the lighter shade with increased weight of hand. No. 2 point will answer for the darker shades by making the lines nearer together and increasing the pressure. Interline parts that require extra color with No. 1 point: the etching may be worked at for a considerable time by interlining and dotting.

Should you by accident or mistake make any marks you wish to expunge, dip a pointed camel-hair pencil into the turpentine bottle, and with its point work up some of the ground on the margin of the plate, and therewith stop out the objectionable marks. When set it will resist the aquafortis.

Bordering the plate.—In cold weather the wax will be too hard to be rolled out with the hand, it must then be placed in moderately warm water until it becomes pliable; then pull and roll it out to about the thickness of a small walking-stick; slightly grease the point of the thumb and two forefingers with deer or mutton fat, press the roll of wax flat as you place it on the border of your plate, with the edge to the varnish, taking great care that the bordering-wax does not go off the varnish. At what you intend to be the darkest corner of your plate pinch out the wax broader, that the height of the wall may increase to that corner where the spout is to be formed with the wax, to prevent spilling the aquafortis in pouring it off.

Biting-in.—Lay your plate flat on a piece of sailcloth larger than the plate, as a protection from any splashings that may be made. Place the spout of your plate in front for the convenience of pouring off. One of your jugs being filled with water, pour it over the plate to prove if there is any leakage in your border; should you find any, pour off the water; let the plate dry, particularly in the defective part; then press down the outer edge of the wax with a piece of stick.

Lay by the side of your plate two or three wedges, (small pieces of firewood,) to be used for tilting the plate should the acid not lay even.

It would be worse than useless to prescribe rules for the proportions of water to be used to the nitric acid, as that will entirely depend on the strength of the acid.

Having proved that your border is sound, pour off the water; then cover the surface of the plate with the aquafortis from No. 2 bottle. If in the course of half a minute the etching on your plate should assume a light-gray coating the mixture will do; but if it should throw up bubbles it is over strong, and more water must be added, but not *on the plate.* The mixture must be placed in the jug, then in the bottle, and afterwards returned to the plate. Should the lines on the plate remain as bright copper after the acid has been on half a minute, it is not strong enough, and some aquafortis out of bottle No. 3 must be added.

Having mixed your aquafortis so that the lines do not produce foam, but continue a gray frosty appearance, the process is going on well. The power of biting-in correctly must depend on the experience you have of your acid.

With a soft camel-hair pencil lightly remove the frosty appearance, taking care that the quill does not touch the ground.

Should any part of the ground be breaking up, that is, the lines becoming united, pour off your acid carefully into the jug. Lay the plate again on the flat, and cover it with water from the other jug, moving it gently with the camel-hair pencil, which should be placed in the water-jug when taken from the acid, or it will soon become useless.

The wash-water from the plate must be thrown away. The first biting now is supposed to be completed, therefore set the plate up endways to dry.

Second biting.—When the plate is perfectly dry, take off with your scraper a spot of ground in the lighter part, to ascertain if the acid has made sufficient indentation. If it has, work up your stopping-out varnish with a camel-hair pencil, and with it cover all the parts you intend to remain light; you must elevate your *rest* so that you do not press the border-wax.

When the stopping-out varnish is dry, which may be ascertained by placing your finger on it and finding that it does not stick, put on the same aquafortis (bottle No. 2) and let it remain until you observe the ground giving way; then pour off the acid, and wash well as before. Put the plate to drain.

Should it be required, more biting may be performed, and the process is the same.

Cleaning off.—Now comes the least agreeable part of the process. Great care must be taken that the plate is perfectly dry; if it be not it may be placed before the fire, but not close enough to melt the wax. Having carefully wiped the sailcloth, lay the plate a little more than half way upon it, but so that the balance remains to the table. Apply a lighted taper or a folded paper match progressively under the wax; pull up the wax as the warmth proceeds; you will find that the slightest warmth answers the purpose. By removing the wax with a knife you are liable to injure the margin, an evil which gives much trouble to remedy. This being the most unpleasant process of engraving, it may be as well to use old gloves; if any of the wax should adhere to the plate, to remove it use a bit of deal firewood cut in the shape of a chisel. Now fix your vice on the same end, and place as you did when laying on the ground. Rub the plate over with a bit of rush candle, using the side, (taking care to cover every part;) have some old soft rags ready; hold the plate up by the vice; heat the back with burning paper as before, until the ground varnish and tallow are melted. Rub off with a soft rag. Should any smut remain, apply a little turpentine; withdraw the vice and wash the spot with turpentine. Rub the plate front, back, and sides, with the rag.

Dab the plate with your bag of rottenstone; pour on it a little sweet-oil; and with your oil-rubber polish the plate with up and down strokes, using considerable pressure: wipe the plate quite clean, and polish off with fine whiting.

Should you have succeeded in biting-in well, the plate is fit for the printer.

Dry point.—Should your work have so far succeeded as to require but little improvement, the dry point may next be used. For this purpose the needle No. 3, well pointed, (as indenture must be made by pressure of the hand,) may be employed. For interlining the parts which are too weak, and uniting lines neglected in the etching, the dry point will be sufficient; but as the pressure will leave a projection or burr on the plate, it must be carefully removed by the sharp scraper: should your plate require more than the dry point can accomplish, recourse must be had to re-biting.

Re-biting.—Heat your plate as before, but make one corner (the one with the least work in it) hotter than the other part.

Rub your ground on the hot corner, and with the dabber take the ground therefrom, and dab quickly over the other part until the whole surface is covered. Prior to laying the ground the plate should be polished with whiting, using a piece of old muslin folded in the shape of a dabber, which will fill the etched lines, and prevent the new-laid ground from entering.

All the parts but those wanting more color must be stopped out as before; again the border-wax must be used. Next follow with acid the same process.

Re-etching.—This is the most certain method of finishing the plate. The ground must be laid as in the first instance, but using a greater body, and with the dabber rubbing it well into the lines, taking care that no whiting remains in the etching marks; for this process the plate should be merely washed with turpentine; a slight extra warmth and good dabbing will render the ground acid proof. The smoking is here dispensed with.

Set up your shade, and work at the plate as in the first instance. Now use No. 3 point, (sharp,) and interline the parts you wish darker and where you want greater strength, crossing the lines, not in direct angles, but lozenge ways.

The plate, cleaned off as before directed, receiving a light oil rubbing with a little rottenstone, and washed off with turpentine, may now be sent to the printer's and a proof obtained.

By repeating the re-etching your plate may be worked up to the color of a line engraving.

In some of the darker parts a graver or lozenge tool may be used; but as it is rather dangerous in the hands of the uninitiated, perhaps it may be best to do without it, as it is apt to slip and make deep lines where none are wanted. Re-biting will produce any extra color that may be wanted with little more trouble, and certainly with less danger.

General instructions.—The following directions may be rather prolix, but will relieve beginners from much trouble, and enable them to avoid many accidents to which engravers are liable.

1st. When using the acid, slightly grease that part of the hand likely to come in contact with it, as a preventive to its making stains, which are not easily eradicated.

2d. When your border-wax has done its duty have it well washed in cold water; then warmed before the fire; pulled out and pressed together again, as the more frequently that is done the more flexible the wax will be for future use.

3d. As your aquafortis will become reduced in strength by exposure to the air, it becomes necessary to add a portion of No. 3 bottle to that of No. 2; and a small quantity of No. 1 bottle to No. 3: No. 1 bottle being the *undilute acid.*

4th. When making a point to your etching-needle work the point round, as, should there be any flat side to the point, it will bite the copper and prevent the freedom of hand required to give spirit to the etching.

5th. With your burnisher you may soften down any part of your etching that appears harsh or crude, by gently passing it over the parts to be reduced in color.

6th. Having your shade before you, which must be between you and the light, you will be enabled to see the marks of the burnisher: fine charcoal and oil will remove them, and the oil-rubber will clear away the charcoal marks. The charcoal can be obtained at any coppersmiths or plate-printers.

7th. If your burnisher is good at first it never requires alteration. The scraper must be occasionally sharpened.

Soft ground.—Take half a ball of *hard ground,* (mixed as described under the head Etching-ground;) to that add a piece of mutton-suet. Melt them well together, observing that the mixture must be thoroughly incorporated; then pour into cold water, and use it as before directed.

Laying the ground.—The process is exactly the same as in laying the etching-ground, with this difference, that the plate does not require so great a heat.

Smoke the plate the same as in laying etching-ground. The ground must be spread as thinly as it possibly can, to cover the plate and bear smoking. The surface of the plate must be alike all over, and quite bright or shining. If any part but the edges appear sooty, it must be cleared off, and the plate polished, as described for etching, and laid again. You may by chance make a good ground at the first melting, but that can scarcely be expected.

It may be as well to test the quality of your mixture before you lay a whole ground. To this end, heat a small portion of your plate; lay some of the ground; smoke it; and let it get quite cold. Obtain some of the finest tissue-paper,—not fine from thinness, but from its even texture. Place a piece of the paper on the patch of ground laid, and with a fine-pointed H pencil make a slight sketch;—a bit of foliage for instance; the paper should slightly stick to the plate: when carefully raised by the two bottom corners, the back of it should clearly show every line made on its surface, only darker.

Should the sketch on the copper have a grainy appearance,—that is, look as if it was dotted all over, the mixture of ground will do. Should the ground adhere to the paper, like marks with pen and ink, the ground must be melted with an addition of *hard ground;* and if even the most tender marks of the pencil do not pull the ground from the plate, the ground must be remelted, and so with one or the other, as the ground may require, until it is fit for work.

As the season has great effect on this ground, the one that will answer for summer will not do for winter, so it may be as well to make or procure two or three sorts of mixtures, and number them according to their several degrees of hardness.'

Having succeeded in mixing your ground, take a piece of tissue-paper twice the size of your plate. Place the plate in the centre, and with a black-lead pencil draw a line all round it. Make the same mark on the other side; then lay the ground as before described. When cold, wipe the back and edges before you take off the hand-vice. This ground being very tender, care must be taken not to touch the face of the plate.

Upon the square marked on the paper your drawing is to be made. If you intend to copy the subject, you must go through the same process as in transferring for the hard-ground etching; only, instead of transferring the red lines on the plate, they must be made within the square marked on the paper. Take care that your tracing is reversed.

If you intend making your drawing on the plate without copy, you must lightly make your design on the square marked with fine-pointed red chalk. Should the subject be figures, every thing must be drawn, as it were, left-handed or reversed.

Fold a clean silk handkerchief in four, lay it flat and smooth on the table, place on it the paper with the chalk sketch downwards. Now, with great tenderness, lay the plate face down, exactly on the square mark of the paper; fold over the back the overplus paper, and fix the sides with four thin spots of sealing-wax near the corners: be sure you do not move the plate on the silk. Take your plate carefully up, and place it for work. Use a rest as in etching, and a hard pencil, H H, on the places you wish to be dark.

There is one drawback to the pleasure of soft-ground engraving; you must finish what you begin the same day; the mechanical part of the work may be delayed. Your drawing finished, pull up your paper by the two bottom corners.

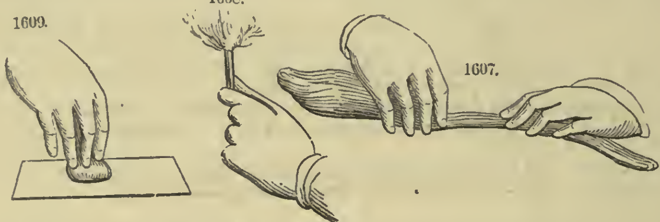
Varnish the border down the same as in etching. The acid used must be much stronger; the border-wax higher and broader in the spout, as you may perhaps have to pour off suddenly.

Biting-in.—In biting-in the signal to pour off your acid is, when you perceive the ground breaking up,—that is, coming up in patches.

During the biting-in the soft camel-hair pencil may be used, but very tenderly. Wash well off with cold water, and place it to dry. For cleaning, see Etching, (supra.)

Should the plate require more finishing, have recourse to the hard ground without smoking.

1609. 1608. 1607.



Aqua-tinta engraving.—In this we have another variety of entertaining engraving; one, moreover, which, unlike the last, is still much practised by professional engravers. It forms the ground-work of many of the best modern prints, and is generally resorted to where the object is to produce a plate, the impressions from which are to be colored. It will at once be recognized by its similarity to an Indian Ink or Sepia Drawing; for in working the plate at press, black and brown inks are used indifferently, as the artist or publisher may direct. Resin forms the ground in this method of engraving.

Without further remark, we proceed to a description of the materials and the mode of employing them.

Aqua-tint ground.—Break some of the best white resin into pieces, sufficiently small to go into the mouth of the bottle used. Fill the bottle up, or nearly so, with spirits of wine. This must be occasionally shaken, until the resin is dissolved. The bottles must have corks, not glass stoppers. Have two other bottles ready; mark the bottles 1, 2, 3. No. 1 is the bottle in which the resin is placed. Pour from the mixture No. 1 into No. 2 one-third; fill this bottle nearly with spirits of wine. Pour into No. 3 bottle rather less of the mixture from No. 1, and nearly fill it with spirits of wine. These bottles must be occasionally shaken, and their contents allowed to settle well before use. The contents of the three bottles must be so mixed that they are one under the other in strength, as the size of the grain to be laid on the plate depends on the quantity of resin each mixture contains. The more of resin the larger the grain.

The spirit must be entirely free from water.

To test the spirit.—Place a small quantity of gunpowder in a silver spoon; pour over it some of the spirit; light the spirit, and let it burn down to the powder. If the powder takes fire and explodes, the spirit is good, and fit for use. If it should remain in the bottom of the spoon black and wet, the spirit has been adulterated with water, and is not fit for the purpose.

Trial of aqua-tinta ground.—Have a tin trough about two inches wide and rather longer than your plate, with a convenient spout at one end; the trough is to act as a receiver of the spirit when poured over the plate; the spout to return it to the bottle.

Laying the ground.—Polish the plate well, as before directed. Place it on a slight slope, the tin trough under the lower edge to receive the spare mixture. As a trial of your ground, pour the liquid from each bottle, and make a small patch in different places at the bottom of your plate. When the liquid has run off to your tin trough lay the plate flat, and with a piece of rag wipe the lower edge. Take a magnifying-glass and look at the grains deposited on the copper.

Having poured the spirit from the trough to bottle No. 1, make choice of the grain most likely to suit

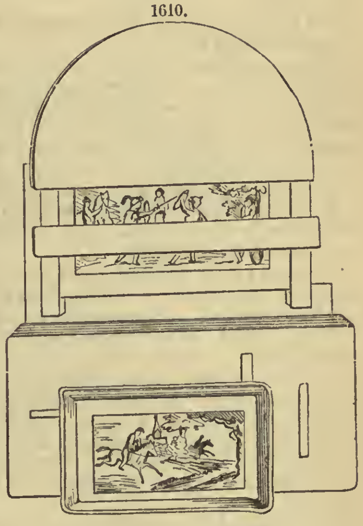
your work, if indeed either of the three should; if not, you must mix the large grain and the small together until it does, letting the mixture settle well before it is used. When you have made one bottle of ground to suit your purpose, make a *memorandum* of the circumstance upon the bottle.

Having removed your trial spots, polish the plate well, and place it as directed for trial, with the side you intend for the foreground next to the tin trough. Pour the mixture along the top of the plate, from one end to the other, until the whole of the surface is covered. As soon as the spirit has run into the tin, lay the plate flat: the sooner it is laid flat the rounder will be the setting of the grain: the longer the plate remains on the slope, the more elongated the deposit of resin will become, which, for some sort of work, will answer better than round—such as broken rock, water-falls, &c.

In most cases it is advisable to make a very fine etching of the subject intended to be placed on the plate prior to laying the aqua-tinta ground; in the end it will save time. The etching must be very light, otherwise the aqua-tinta ground will hang round the lines and form a ray of light. Should the etching be strong, it will require being filled up with wax, and polished off before laying the ground. Engravers send the plate to the printer's, and have it filled up with ink, which is much the best method, where it can be resorted to. If obliged to use wax, the plate must be heated rather above what is required for the etching-ground, the surface wiped off, and polished with the soft part of the hand slightly rubbed with whiting.

Having laid the ground to your satisfaction, the next proceeding is stopping out the lights.

1610.



Stopping out the lights.—Place on the left side a small looking-glass in a stooping forward position; lay before it the drawing intended to be worked from, with the base or foreground towards the bottom of the glass; you will then see the subject reversed in the glass, which will enable you to copy with greater freedom.

Go over the margin as directed under the head Etching. For this a camel-hair pencil, and the same pot of varnish, with a little more lamp-black added, and well worked together, should be used. Stop out all the white lights you observe in the drawing. By the time you have done this the varnish on the margin will be dry or set; if not, the plate must remain until it is.

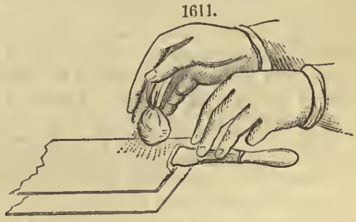
Then go over the margin again with the same varnish, and let that set hard.

Now place up your border-wax as before directed, making the spout rather larger, that you may be enabled to pour off the acid quickly, if necessary.

Use the same aquafortis as for etching, but the strength somewhat increased, as it will have to remain on the plate a much shorter time.

Lay your plate an inch or so over the front of the table, with the piece of sailcloth underneath, having small wedges of wood ready to be used should the acid not float evenly.

1611.



Put on the acid rather quickly; running it from the bottle to the jug, then on the plate; the other jug, having been filled with cold water, should be kept ready for washing off. When the acid has entirely covered the plate, the surface should immediately assume a frosty appearance, but not come up in bladders. Little more than a minute may be enough for the acid to remain on the plate; pour it into the jug as quickly as you can without spilling it; immediately wash off with cold water; have a receiver for the wash-water, as it must be thrown away.

Wait until the surface of the plate is dry. If in a hurry, blow it dry with bellows. When you adjust your plate for work, should any spots of moisture remain on the surface, carefully take them up with blotting-paper.

Now, with the same varnish, stop out all the second lights. To prevent injury to your border, place two blocks or old books under the ends of your rest.

When the second stopping out is set, put the plate through the same process with the same acid.

Again dry the plate, and stop out the third light parts; when set, apply the acid, but let it remain on rather longer; wash, &c., as before directed.

You will now have all the flat tints, and only require the very dark ones. With your magnifying-glass ascertain if the spots of resin remain on the plate; if so, it will bear biting again.

Should the ground remain sound enough to stand another application of the nitre, you must prepare a mixture called touching stuff.

Touching stuff.—Burn a good-sized cork to ashes, and take a piece of whiting about the size of a filbert; mix them together with treacle; then add as much ivory-black as will make the mixture a dark color, by the addition of a small quantity of sheep's or ox gall; it works almost as free as the varnish. Make the composition to a lump. A small quantity to be used with water when required.

Again lay the plate for work. Paint over all the parts that are required to be very dark, such as projecting foliage, and all sharp shadows, with the touching stuff. I say paint, for you must load all the touches with as much of the mixture as can be placed on them.

When the touching stuff is dry, mix some thin turpentine varnish, slightly colored with lamp-black, and with a larger brush go over the whole of the plate.

When this last varnish is set, pour on some very weak acid and water—the former washings of the plate will do. With the soft camel-hair pencil used for the acid, work up the touching stuff until the whole comes off; then wash the plate clean with cold water, and again apply the acid.

For this last biting the acid may remain on the plate as long as the ground will stand. This may be ascertained by clearing your plate with the camel-hair pencil, and using the magnifying-glass.

The plate must now be cleaned. Release your border-wax as before described.

On this tint the oil-rubber should be very carefully used.

The plate being quite clean, place it under the shade. You will find your tints or bitings rather sharper against each other than you wish.

The burnisher is to do away with this by rubbing with pressure the parts to be reduced in color. The parts to be burnished should be slightly touched with the oil-rubber. Aqua-tint engraving requires some skill in the use of the burnisher, which can only be acquired by practice.

The scraper will be found very useful for bringing out sharp lights and modulating the darker parts.

Should you have failed in making the first ground tell to your satisfaction, the plate must be polished, and another ground laid. The second ground must be larger than the first, that is, contain more resin.

The bordering, biting, and stopping out are as before. The plate should be sent for *proof* before the second ground is laid.

When you have the proof you will be able to ascertain where you require increase and where reduction of color. The burnisher must reduce, the increase can only be had by laying another ground.

Ground to etch on.—Mix a small quantity of turpentine varnish with turpentine very slightly colored with black, but only sufficiently so to render the lines made by the needle perceptible. With this thin varnish and a good-sized camel-hair brush, go over the plate longways; when that is set, repeat the coating crossways; let it set, and lay it by for a night, if convenient.

The etching finished, border and bite as before directed, but with stronger acid.

Incidental instructions.—A few hints or cautions, apparently on trifles, may be found useful, and enable the beginner to avoid many troublesome obstacles which, neglected, prevent engraving becoming an entertaining amusement.

Great care must be taken, while laying the ground, that there is not much dust floating in the air; for should the slightest particle of fluck lodge on the plate whilst wet, it will cause, what the engravers call, "an accident." Wherever the speck falls, the resin will corrode around it, and consequently form a white spot on the ground where the acid has been applied. These "accidents" are of little consequence, unless they should happen on the sky. To do away with such light places, the chalk tool or dotter must be used, which is simply a bent graver.

From pouring your ground mixture backwards and forwards, it is likely to become foul; it should then be passed through a double piece of clean muslin, and put away in a bottle to settle.

The burnisher acts as principal in forming a good sky and background. As the action of the acid will leave all the tints with a sharp edge, they must be softened down with the burnisher. Every fresh aqua-tinta ground laid should be increased in the size of the grain, or the ground will become murky.

To enrich and darken the foreground or foliage, etching over the parts with the etching-ground above described, is much the easiest method.

Resin-ground engraving.—This style of engraving is well adapted to ornamental work, as great depth of color can be obtained. The process is extremely simple.

The best white resin should be reduced to powder by pestle and mortar, then placed in a fine doubled flannel, and tied up in a bag. The plate must be heated as in laying etching-ground, and the bag of resin then powdered on the surface. The best plan is to lay the plate on a table, so that you may use both hands. With the bag of resin pendent in the right hand, strike it against the left, (the bag must be held some distance from the plate,) which will force the powdered resin to escape from the flannel bag, and falling on the hot plate, will there fix itself in small spots, something similar to the aqua-tint deposit, but much more enduring.

The stopping out process is exactly the same as in the aqua-tint.

By repeating the process with the flannel bag a positive black ground may be procured, as dark and more enduring than a mezzotinto ground, which may be scraped on much in the same way.

Figs. 1608 to 1611, represent the apparatus, and the hand-craft to bring it into action;—such as heating the plate, laying the ground, smoking the ground, bordering the margin, biting-in the etching, taking off the border, and polishing the plate.

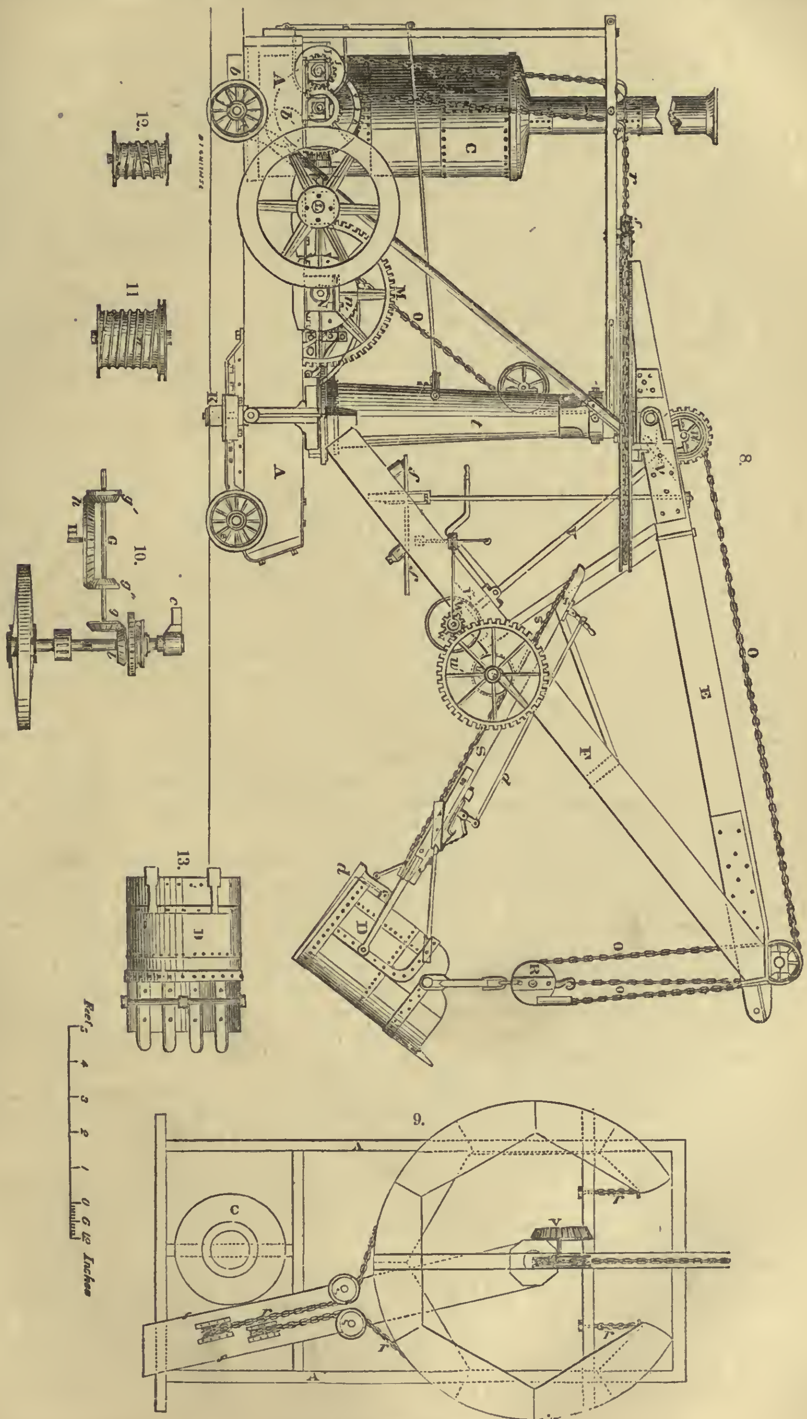
Etching on glass.—The glass is covered with a thin ground of beeswax, and the design being drawn with the etching-needle, it is subjected to the action of sulphuric acid sprinkled over with pounded flour or Derbyshire spar. After four or five hours this is removed, and the glass cleaned off with oil of turpentine, leaving the parts covered with the beeswax untouched. This operation may be inverted by drawing the design on the glass with a solution of beeswax and turpentine, and subjecting the ground to the action of the acid.

Stippling is also executed on the etching-ground by dots instead of lines made with the etching needle, which, according to the intensity of the shadow to be represented, are made thicker and closer. The work is then bit in.

Etching on steel is executed much in the same way as in the process on copper. The plate is bedded on common glazier's putty, and a ground of Brunswick black is laid in the usual way, through which the needle scratches. It is then bit in, in the way above described.

EUDIOMETER. An instrument used to ascertain the quantity of oxygen contained in any given bulk of elastic fluid.

EXCAVATING MACHINE. This machine, which is the invention of the late Mr. Otis of New York, is an application of steam-power to the purposes of excavation and dredging; and for the former



SCALE.—16 feet — 3 inches

purpose, appears greatly superior to any thing which has hitherto been achieved in excavating machinery. The accompanying engraving presents the principal side elevation (Fig. 1612) of the machine, which brings all the working parts sufficiently into view; Fig. 1613 a plan of the horse-shoe pulley and crane top, the dotted lines show the position of the lower framing or stage and boiler; Fig. 1614 shows the crank shaft and gearing; Fig. 1615 the main drum; Fig. 1616 the main drum for working the excavator; and Fig. 1617 a plan of the excavator.

The whole of the details of this machine, which are very elaborate and complete, of course cannot be attempted in an article of this nature; we will, however, describe as much of the details and its principal feature as are necessary to a proper understanding of the several movements of the machine, and then describe each of those movements separately. The machine consists of a strong horizontal wooden framing or stage A, mounted upon two pairs of railway wheels b, for locomotion, which run on temporary rails, laid down as may be required; on the one end of the stage is fixed a cylindrical boiler C, and the gearing for turning the crane round. In the middle is placed the gearing for working one of the motions of the excavator D; and, at the other end is placed the wooden crane E, in form similar to an ordinary timber crane, on the diagonal brace of which is placed a platform f, on which an assistant stands; and gearing W, for working another motion of the excavator D. To support the machine laterally, strong brackets or arms project on either side, the ends of which are furnished with screws to adjust the machine to the inequalities of the surface of the ground.

The excavator or shovel D, (Figs. 8 and 13,) is formed of stout boiler-plate, and is firmly riveted together; it is of a box shape, having one end open; on the lower edge are four tangs or points, which serve to penetrate and loosen the soil; the other end is hung on swivel hinges, and fastened by a spring d, which may be set at liberty by means of the lever and rods a, Fig. 8.

The machine is made to perform three distinct movements; 1st, the digging movement; 2d, the turning movement; and 3d, the locomotive movement.

The Digging Movement consists of two motions, one for drawing the excavator forward, and the other for driving it into the ground, both of which are done simultaneously: the first motion is performed in the following manner. On the horizontal stage A, and in front of the boiler C, is placed a small high-pressure engine, (not shown in the engraving,) the connecting rod of which acts upon the crank c, and gives a rotary motion to the shaft L, and with it the pinion l, (Fig. 10,) which works into the large wheel M, mounted on the shaft N, upon which is fixed a large channelled barrel or drum n, (Figs. 8 and 11,) round which the hauling chain O, is coiled; this chain passes upwards through the hollow crane post, over the indented pulley P, to a double pulley fixed at the jib-head, thence round the blocks R, to which the excavator is suspended, as the chain wound up draws the excavator out of the ground both in a forward and upward direction, when driven into the ground by the second motion. This last motion is communicated by the chain traversing over the indented pulley P, to another gearing. On the axle of the indented pulley P, is fixed a bevelled wheel v, (Fig. 9,) which works into a similar one v', (Fig 8,) mounted on to the upper end of the oblique shaft V, on the lower end of which is a corresponding bevelled wheel v'', working into another w, fixed upon the shaft W; upon this shaft is a pinion w' which takes into the large spur wheel u', mounted upon a shaft, upon which is a channelled drum u, round which is coiled the chain s, attached to the diagonal wooden arms S; on the lower end of these arms is fixed an iron yoke, to which is suspended on pivots the excavator. By this arrangement, as the main chain O passes over the pulley P, motion is communicated to the shaft for the purpose of forcing downwards in a diagonal direction the arms S, and with them the excavator into the ground. A man stands upon the stage f, for throwing in and out of gear this apparatus, and to regulate the motion for lowering or raising the excavator.

The next motion to be described, is for the purpose of turning the crane round either to the right or to the left; this is effected by another gearing in the following manner. On the first crank shaft I, is fixed a bevelled wheel l, (Fig. 10,) which works into a similar wheel g, mounted on to the end of a horizontal shaft G, upon which are placed loose two bevelled wheels $g'g''$, either of which can be thrown in or out of gear so as to work, as may be required, into the large bevelled wheel h, mounted upon the shaft H; upon this shaft is a pinion h', which works into the wheel j, fixed on the shaft J; upon this shaft is fixed an indented pulley j', round which the chain r is coiled, and passes upwards over pulleys s, round either side of the horse-shoe pulley, to the ends of which it is fixed by iron bolts; the horse-shoe pulley is fixed by means of strong iron stays to the crane, and when it is made to revolve, the crane-jib is turned round on the stationary post t, either to the right or to the left as may be required, and empties the contents of the excavator into a wagon or barrow.

The Progressing Motion is effected by placing on the hind wheel axle a strong wheel, shown by a circle b, (Fig. 8,) which communicates with a pinion b', on a shaft, as shown by a dotted circle; motion being given to the shaft above by the bevel gearing described in the last motion, a forward or backward motion of the machine is obtained.

We have no precise data as to the cost of the machine or the quantity of work that can be performed by it, further than a rough estimate, which states that the machine is capable of digging 1000 cubic yards of earth *per day*, and that a machine complete costs about 6000 dollars.

EXPANSION. See ENGINE AND STEAM.

EXPANSION JOINT. A stuffing-box joint connecting pipes, so as to allow one of them to slide within the enlarged end of the other when the length increases by expansion.

EXTRADOS. The exterior curve of an arch, measured on the top of the voussoirs, as opposed to the soffit or intrados.

FACADE. The face or front of any considerable building to a street, court, garden, or other place.

EXHAUST-PORT. The exit passage for the steam from a cylinder.

EXHAUST-VALVE. The valve in the eduction passage of the steam cylinder of a Cornish Engine

FAN. A wheel with vanes revolving in a case or box, used for the production of a current of air or gas. The principle of its operation depends on the law of centrifugal forces; the air is drawn in at the centre and discharged at the periphery of the wheel: it may therefore be applied either to draw air from any place, or to force it into any place, as may be best suited to the purpose intended. The fan is employed for draft or suction—in cotton pickers, for the extraction of dirt and for the formation of a lap. It is used generally for blast to furnaces (see Blowing Machines) and for agricultural purposes, as in the winnowing of grain; for ventilation it is used indiscriminately for draft or blast. When used to promote the rapid combustion of fuel, it is evident, that whether the fan be placed in the smoke flue, and the air be drawn into the fire, or whether it be placed in front of the fire, and the air forced in, the result will be in most cases nearly the same. It is applied in both ways, but there are some mechanical difficulties that interfere with the economical use of it in the former method, and it is therefore almost universally applied to fires as a blowing machine.

Of the practical working of the fan. The power required to drive it, the proper velocity to be given to it, and the density of air required, we know no more satisfactory experiments than those made by W. Buckle, Esq., and published in the Practical Mechanic's and Civil Engineer and Architect Journals, from which we extract his observations and the results of his experiments.

"The experiments were made with a fan 3 feet $10\frac{13}{16}$ inches diameter, the width of the vanes being $10\frac{3}{4}$ and the lengths 14 inches; the eccentricity of the fan $1\frac{7}{16}$ inches, with reference to the fan case, the number of vanes being 5, and placed at an angle of 6° to the plane of the diameter; the inlet openings on the sides of the fan chest $17\frac{1}{2}$ inches diameter, the outlet opening 12 inches square; the space between the tips of the blades and the chest increasing from $\frac{5}{8}$ inch on the exit pipe to $3\frac{1}{2}$ at the bottom, in a line perpendicular with the centre. To the blast pipe leading to the tuyeres a slide valve was attached, by means of which the area of the discharge was accurately adjusted to suit the required density."

No. of Experiments.	Velocity of the tips of vanes in feet per second.	Density of air in ounces per square inch.	Height of mercury in inches equivalent to the density.	Height of column of air equivalent to the density of air in feet.	Area of discharge pipe in square inches.	Indicated horse power.	Theoretical velocity of air in feet per second.
1	236·8	9·4	1·175	1093·10	closed.	9·60	264·4
2	220·8	7·9	·987	918·20	"	7·54	242·4
3	204·16	6·9	·862	801·91	"	6·68	226·5
4	185·28	5·6	·7	651·21	"	5·36	204·1
5	171·5	4·5	·562	522·8	"	3·82	182·9
6	144.10	3·5	·437	406·5	"	2·214	161·2
7	221·8	7	·875	814·01	37·5	13·31	228·24
8	217·09	7	·875	"	38·125	11·02	228·24
9	221·8	6	·750	697·72	48·75	13·81	211·3
10	213·3	6	·750	"	53·125	12·54	211·3
11	192·2	6	·750	"	24·375	6·43	211·3
12	221·8	5	·625	581·43	60·	14·26	192·9
13	211·48	5	·625	"	65·	13·05	192·9
14	193·9	5	·625	"	52·5	8·75	192·9
15	174.5	5	·625	"	22·5	4·53	192·9
16	221·8	4	·5	465·1	69·	14·19	172·5
17	211·48	4	·5	"	75·	13·33	172·5
18	196·68	4	·5	"	65·62	9·53	172·5
19	177·62	4	·5	"	78·125	11·32	172·5
20	155·11	4	·5	"	33·125	3·3	172·5
21	200·7	3	·375	348·86	82·68	10·15	150·
22	174·5	3	·375	"	102·72	10·61	150·
23	157·8	3	·375	"	89·63	7·56	150·
24	134·5	3	·375	"	56·25	2·98	150·
25	160·5	2	·250	232·5	151·6	9·1	122·
26	138·15	2	·250	"	124·125	5·89	122·
27	155·1	1	·125	116·28	264·9	9·38	86·26
28	138·15	1	·125	"	264·9	7·27	86·26

By this table it will be seen that there are certain velocities with which the tips of the fans should move according to the required density of air, and that there are certain laws which govern these velocities.

The centrifugal force or density of the air coincides with the results obtained by the law of falling bodies; that is, when the velocity is the same as the velocity which a body will acquire in falling the height of a homogeneous column of air equivalent to a given density.

Having given the velocity of the air, and the diameter of the fan, to ascertain the centrifugal force—

Rule.—Divide the velocity by 4·01, and again divide the square of the quotient by the diameter of the fan. This last quotient multiplied by the weight of a cubic foot of air, at 60° Fahrenheit, is equal to the force in ounces per square foot, which, divided by 144, is equal to the density of air per square inch.

Or, substituting the following formula, we have $D = N \times \cdot000034$. Where D is the density of the

air in ounces per square inch, and N the number of revolutions of fan per minute, and V the velocity of the tips of the fan in feet per second.

Having given the density in inches of mercury, (1 inch of which is equal to 8 oz. pressure.) To find the velocity which a body would acquire in falling the height of a column of air equivalent to that density:

Rule.—Multiply the density in inches of mercury by 930·3, and this product by 64. The square root of the last product will be the velocity in feet per second, or more simply—

Multiply the square root of the density in inches of mercury by 244, and the product will be the velocity.

It will be seen by the table that the velocity of the tips of the fan is practically somewhat less than this theoretical velocity, and from the experiments we fix the laws which govern the velocity of the tips of the fan 9-10th of the velocity a body would acquire in falling the height of a homogeneous column of air equivalent to the density.

Experiments were made as to the proper size of the inlet openings, and on the proper proportions to be given to the vane. The inlet openings in the sides of the fan chest were contracted from 17½, the original diameter, to 12 and 6 inches diameter, when the following results were obtained:

First, that the power expended with the opening contracted to 12 inches diameter, was as 2½ to 1 compared with the opening of 17½ inches diameter; the velocity of the fan being nearly the same, as also the quantity and density of air delivered.

Second, that the power expended with the opening contracted to 6 inches diameter, was as 2½ to 1 compared with the opening of 17½ inches diameter; the velocity of the fan being nearly the same, and also the area of the efflux pipe, but the density of the air decreased one-fourth.

These experiments show that the inlet openings must be made of sufficient size, that the air may have a free and uninterrupted action in its passage to the blades of the fan, for if we impede this action we do so at the expense of power.

With a vane 14 inches long, the tips of which revolve at the rate of 236·8 feet per second, air is condensed to 9·4 ounces per square inch above the pressure of the atmosphere, with a power of 9·6 horses; but a vane 8 inches long, the diameter at the tips being the same, and having, therefore, the same velocity, condenses air to 6 ounces per square inch only, and takes 12-horse power.

Thus, the density of the latter is little better than 6-10th of the former, while the power absorbed is nearly 1·25 to 1. Although the velocity of the tips of the vanes is the same in each case, the velocities of the heels of the respective blades are very different; for, whilst the tips of the blades in each case move at the rate of 236·8 feet per second, the heels of the 14-inch blades move at the rate of 90·8 feet per second; and the heels of the 8-inch move at the rate of 151·75 feet per second; or, the velocity of the heel of the 14 inch moves in the ratio of 1 to 1·67, compared with the heel of the 8-inch blade. The longer blade approaching nearer the centre, strikes the air with less velocity, and allows it to enter on the blade with greater freedom, and with considerable less force than the shorter one. The inference is, that the short blade must take more power at the same time that it accumulates a less quantity of air.

These experiments lead me to conclude, that the length of the vane demands as great a consideration as the proper diameter of the inlet opening. If there were no other object in view, it would be useless to make the vanes of the fan of a greater width than the inlet opening can freely supply. On the proportion of the length and width of the vane, and the diameter of the inlet opening, rest the three most important points, viz., *quantity*, and *density* of air, and expenditure of *power*.

In the 14-inch blade, the tip has a velocity 2·6 times greater than the heel; or, by the laws of centrifugal force, the air will have a density 2·6 times greater at the tip of the blade than that at the heel. The air cannot enter on the heel with a density higher than that of the atmosphere, but in its passage along the vanes, it becomes compressed in proportion to its centrifugal force. The greater the length of vane, the greater will be the difference of the centrifugal force between the heel and the tip of the blade; consequently, the greater the density of the air.

Reasoning, then, from these experiments, I recommend, for easy reference, the following proportions for the construction of the fan:—

Let the width of the vanes be one-fourth of the diameter.

Let the diameter of the inlet openings in the sides of the fan chest be one-half the diameter of the fan.

And, let the length of the vanes be one-fourth of the diameter of the fan.

In adopting this mode of construction, the area of the inlet openings in the sides of the fan chest will be the same as the circumference of the heel of the blade, multiplied by its width; or the same area as the space described by the heel of the blade.

The following table gives the sizes of fans varying from 3 to 6 feet diameter:—

TABLE OF BEST PROPORTIONS OF FANS.

Diameter of Fan.		Width of Vane.		Length of Vane.		Diameter of inlet opening.	
ft.	in.	ft.	in.	ft.	in.	ft.	in.
3	0	0	9	0	9	1	6
3	6	0	10½	0	10½	1	9
4	0	1	0	1	0	2	0
4	6	1	1½	1	1½	2	3
5	0	1	3	1	3	2	6
6	0	1	6	1	6	3	0

I recommend the proportions in the above table for density ranging from 3 to 6 ounces per square inch, and for higher densities, viz. from 6 to 9, or more ounces, the sizes given in the following table:

Diameter of Fan.		Width of Vane.		Length of Vane.		Diameter of inlet opening.	
ft.	in.	ft.	in.	ft.	in.	ft.	in.
3	0	0	7	1	0	1	0
3	6	0	8½	1	1½	1	3
4	0	0	9½	1	3½	1	6
4	6	0	10½	1	4½	1	9
5	0	1	0	1	6	2	0
6	0	1	2	1	10	2	4

The dimensions of the above tables are not laid down as prescribed limits, but as approximations obtained from the best results in practice.

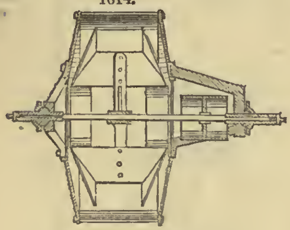
Experiments were also made with reference to the admission of air into the transit or outlet pipe. By a slide the width of the opening into this pipe was varied from 12 to 4 inches. The object of this was to proportion the opening to the quantity of air required, and thereby to lessen the power necessary to drive the fan. It was found that the less this opening is made, provided we produce sufficient blast, the less noise will proceed from the fan; and by making the tops of this opening level with the tips of the vane, the column of air has little or no reaction on the vanes.

As to the pressure of the blast commonly required in smithies, the range is from 4 to 5 ounces per square inch. And an ordinary eccentrically placed fan, 4 feet diameter—the blades 10 inches wide and 14 inches long, and making 870 revolutions per minute—will supply air at a density of 4 ounces per square inch to 40 tuyeres, each being 1⅝ inch diameter, without any falling off in density.

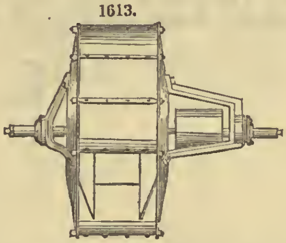
The above embody the results and deductions from Mr. Buckle's experiments on the common form of eccentrically placed fan; but, besides this form, there is a great variety of others, on which, it is true, no scientific experiments have been made of their working, but which, in practice, have given very satisfactory results. We give drawings and slight descriptions of two in common use.

Figs. 1612, 1613, and 1614, represent the fan of F. P. Dimpfel, of Philadelphia.

1614.



1613.



1612.

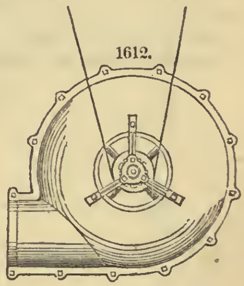
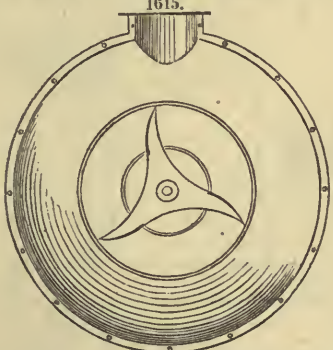


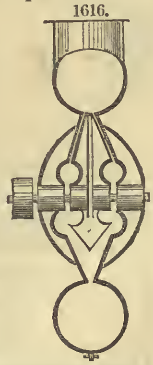
Fig. 1612 is a side view. Fig. 1613 an end view, looking into the outlet pipe. Fig. 1614 a section. It will be seen that the vanes of the fan are in the form of a trapezium, and that the air-chamber not only extends all round the periphery of the fan, but also at the sides.

This fan is in use at the Novelty Works, New York; where it is also made, and is highly recommended by the proprietors of various foundries and forges where it is in operation.

1615.



1616.

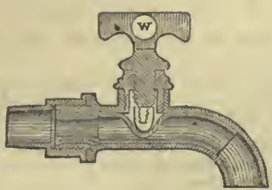


Figs. 1615 and 1616 represent sections of a fan made by Wm. Mason, Taunton, Mass. The vanes are three in number, of a triangular form; the air-chamber is circular, and extends entirely round the fan; the arms of the fan are curved, and in movement present the convex side to the impelled air. The construction of this fan is extremely simple: the fan is cast entire in one piece; the case enclosing the fan and forming the air-chamber, is cast in halves and bolted together. This fan is extensively used, and gives general satisfaction. Both Dimpfel and Mason's fans are made of various sizes to suit the purposes for which they are designed.

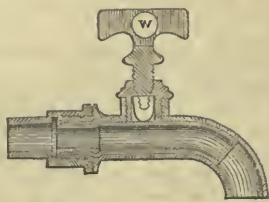
FAUCET. A cock used to draw liquids from casks or other reservoirs; in its common form it is well known. Such as are used to drive in the small bung of fermented liquor casks are made very strong, often with a straight tube which is driven into the cask, and the cock itself at right angles to the

tube. Figs. 1617[1] and 1617[2] represent Jenning's India Rubber Tube Cock. Its construction is quite simple; a vulcanized rubber tube is inserted in the tube of the cock, and held at its interior end by the insertion of a metallic thimble. When the screw W is turned down, the tube is compressed, and the liquid shut off; by the raising of the same the tube regains its natural form and the discharge com-

1617. [1]



1617. [2]



mences. The cock offers a straight and uninterrupted passage for liquids or gas, the working parts having no connection with the interior. From the certainty of its action, and the impossibility of its sticking up or down, it is well worthy attention. As these cocks can be made in iron, a great saving is effected, and they answer as well as those manufactured in brass.

FEED APPARATUS. See Details of Engines.

FEEDER. A cut or channel, by which a stream or supply of water is brought into a canal; sometimes the stream of water itself is called the feeder.

FELLOES. The curved pieces of wood forming the rim of a carriage, cart, or other wooden wheel.

FELLOE MACHINE. This is a machine for cutting felloes of wheels out of plank, on which valuable improvements have been made by Joshua and Levi Adams, and T. H. Mores, of Amherst, Mass.

1618.

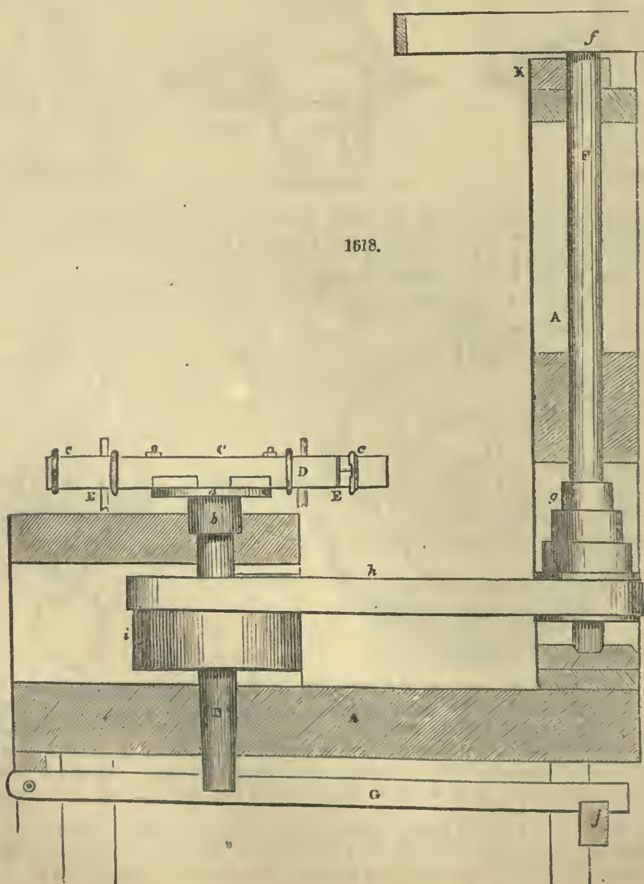
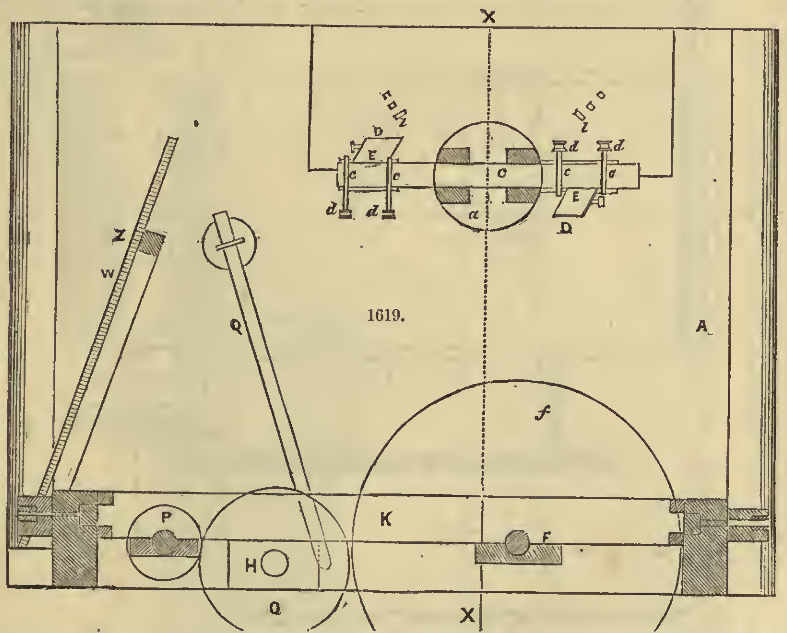


Fig. 1618 is an elevated section of the machine at the line X X of Fig. 1619, which is a horizontal view with the friction wheels removed. The same letters refer to like parts on both the figures.

A is a frame, B is an upright shaft resting in a movable step at its lower end, and having a circular plate *a*, secured to its upper end, above the hub *b*. C is a horizontal beam secured between projections on the upper surface of the circular plate. D are angular metallic boxes with flanges on their sides attached to the beam by the straps *d*. E are the cutters of the desired form passing through openings in the boxes and adjusted by screws. F is an upright shaft resting in a step in the frame and turning in a box screwed to a vibrating timber at its upper end, and with a friction wheel and pulley *f* at the top, and a gang of pulleys *g* below, around which is seen the band *h* extending around a pulley *i* on B. G is a lever arranged below the frame and secured at one end to the front of the same by a pin upon which it moves, and at its opposite end upon a similar lever *j*, which is connected to a cross-head, moving between upright ways. H is a vertical screw shaft passing through a screw in the cross-head, and having a button or shoulder at its lower end, which shoulder turns in a permanent block in the frame. Q is a lever moving on a fulcrum, and connected at the end by a rod, which is connected to a lever below the frame, having a weight hung on its upper end to counterbalance the weight of the vertical shaft of cutters and levers to relieve the screws of part of the pressure and prevent it from wearing. K, Fig. 1619, is a horizontal beam containing the boxes in which the upper end of the upright boxes turn, and it is provided with tennons at the ends which fit into mortises in the vertical parts of the frame and has cords attached to its ends, one of which, with a weight, passes over a pulley in the outside, and the other cord passes over another pulley and is attached to a lever Z W, moving on a fulcrum, for lowering the cross-head by lowering the said lever.



When it is desired to cut a felloe, the plank from which it is to be cut is placed upon the tables and firmly secured by the dogs and clamps *l*. The upright shaft is then set in motion by the friction wheels being brought in contact by the lever, and therefore the cutter shaft by the band *h* is set in motion. The cutters E E, are set in the cutter heads by the straps *d d*, so that one cutter shall move in a circle, cutting the outside of the felloe and the other cuts the inside circle, while the cutter shaft can be raised or lowered by the lever G, to cut the required depth. The dogs and clamps can be shifted on the table for larger or smaller felloes, and the cutters can be shifted on C C C, to correspond with the same.

FELT-CLOTH MACHINERY, Arnold's. From the specification of the inventor, patented June 10 1851. The following is a description of the same.

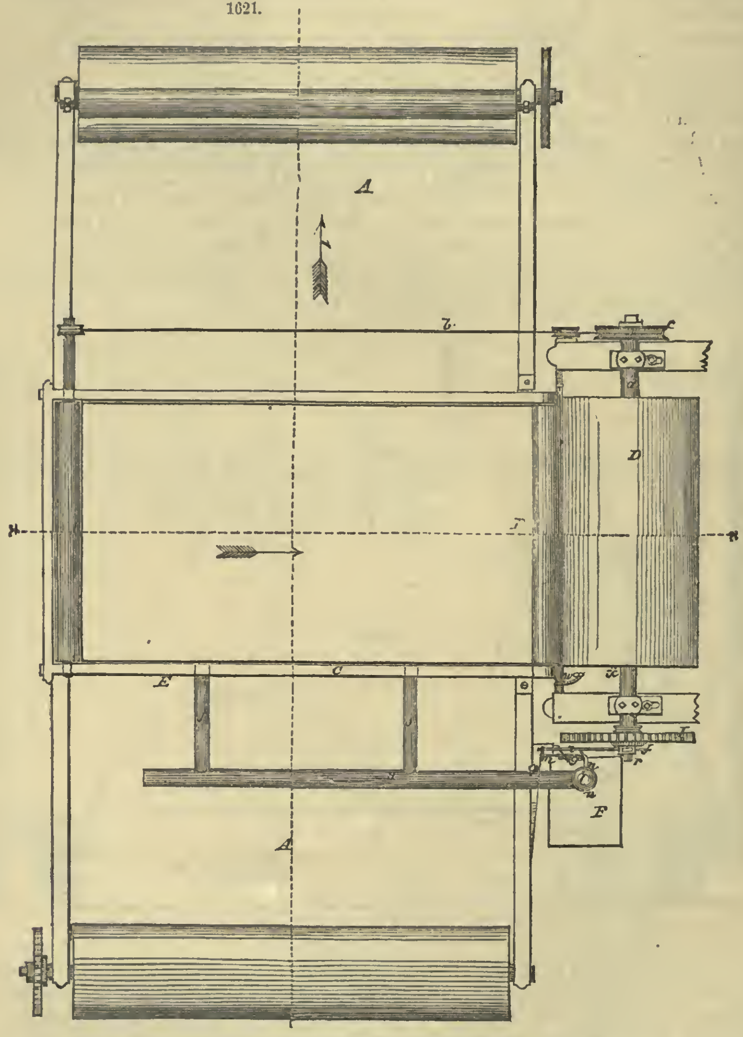
Fig. 1620 is an elevation of the machinery; fig. 1621 is a plan or bird's-eye view of that part of the same to which my invention relates; fig. 1622 is a vertical section through the line *x x* of fig. 1622, looking from the opposite side to fig. 1620; fig. 1623 is a vertical section through the line * * of fig. 1621; fig. 1624 is a horizontal section of the vacuum-box and tubes communicating with the apparatus for producing the vacuum. Figs. 1625 and 1626 are sections taken at right angles to each other of the vacuum pipe. Similar letters of reference indicate corresponding parts in each of the several figures.

My improvement relates to a new and improved mode of carrying webs or sheets of *fibrous material* and, *when employed* in the manufacture of *felt-cloth* is for the *purpose* of *carrying the weft across* and *depositing it upon the warp.* Felt-cloth is manufactured by crossing the fleeces or cardings of wool from the carding machines, and then pressing, blending, or matting them together into a sheet of compact texture. The usual mode of conveying the weft across the warp is by means of endless chains carrying

combs with hooked teeth, from which teeth it has to be released in order to be deposited on the warp These teeth frequently allow some portion of the material to fall or slip off too soon.

This difficulty I design to obviate by my improvement, which consists in the employment of an apron of some material pervious to air, as for instance hair-cloth. Between the rollers of this apron, and between its upper and lower folds, I place a hollow box or chamber which nearly fills the entire space; the

1621.



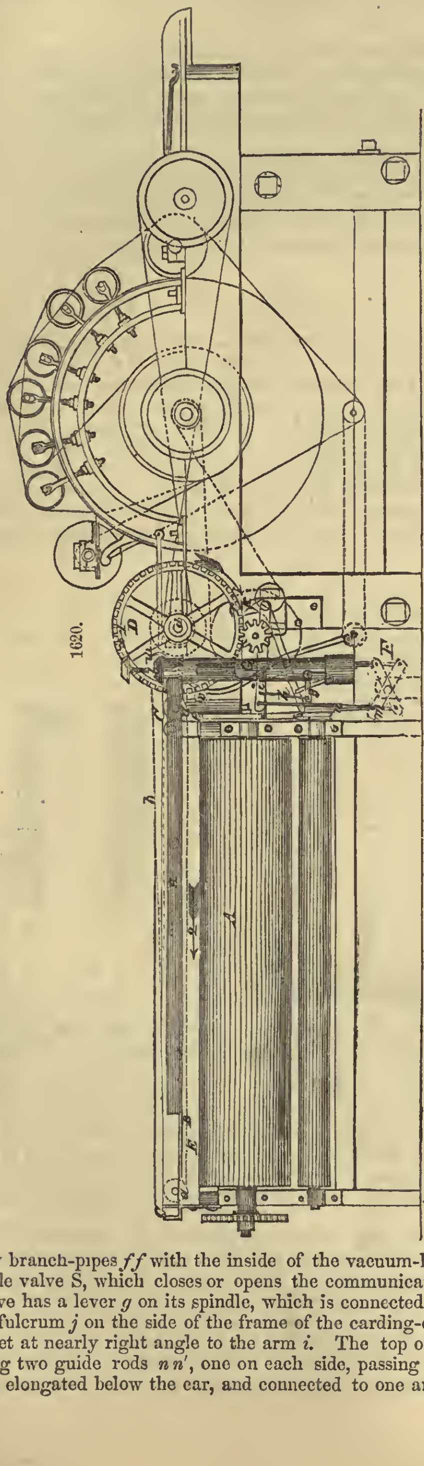
bottom of this box is thickly perforated all over with small holes, and it communicates by pipes from one or both sides with a fan, blower, or other apparatus capable of withdrawing the air and forming a vacuum within. The air being withdrawn from the box, the external air rushes through the apron and through the perforations in the bottom of the box to supply its place, and any light or fibrous material will be drawn towards the apron and securely held under it by the pressure of the atmosphere, without any liability to fall off till the desired moment, when the communication with the blower is cut off.

The carding machine represented in fig. 1620, which supplies the fleece or carding for the weft, does not differ from other machines in use, and therefore needs no particular description here; that which supplies the warp is not shown.

A A is the apron which carries the warp, which is the same as usually employed; it moves in direction of the arrows 1 (figs. 1621 and 1623), and carries the warp on the top. B B is the apron carrying the weft, which, as has been before stated, is of material pervious to air; it runs on two collars $a\ a'$, in a frame $c\ c$, supported above, the frame carrying the warp apron. The apron B B receives motion in the direction of arrows 2 2 (figs. 1620, 1621 and 1622,) through roller a', by a band b, from a pulley c, on the shaft d, of the doffer D of the carding machine.

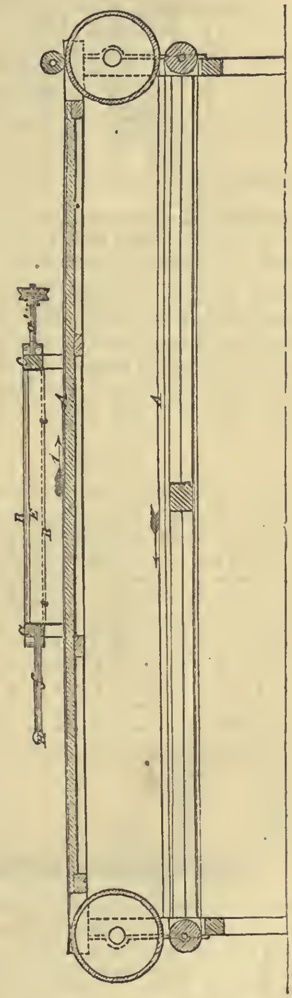
E is the vacuum-box, which is made of any sheet metal, and is of a length nearly equal to the space

between the rollers $a\ a'$, of the width of the warp, and of a depth nearly equal to the space between the upper and lower folds of the apron; its bottom, perforated all over with holes e, e, e, e, touches or nearly touches the lower fold of the apron. A rotary fan in a box F, is placed near the machine, or in any suitable position for operating on several machines at the same time; a pipe G proceeds upwards from the box of the fan, having a pipe H leading from it near the top which communi-



1620.

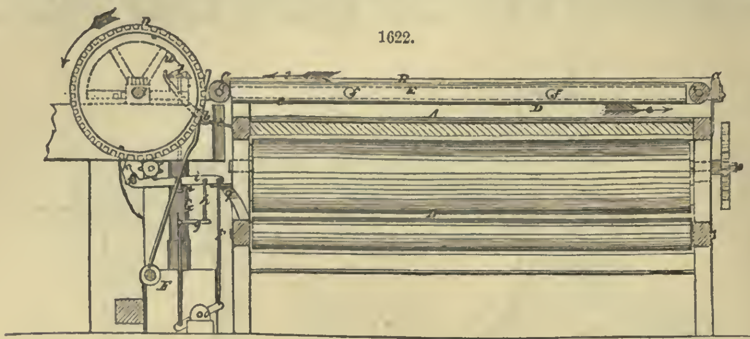
1623.



cates by branch-pipes $f\ f$ with the inside of the vacuum-box. In the lower part of the pipe G there is a throttle valve S, which closes or opens the communication between the fan and the vacuum-box E. this valve has a lever g on its spindle, which is connected by a rod h to a long arm i of a lever hung on a fixed fulcrum j on the side of the frame of the carding-engine, the same lever having a shorter curved arm k set at nearly right angle to the arm i. The top of the pipe G is open, but is covered by a valve l, having two guide rods $n\ n'$, one on each side, passing through ears on the outside of the pipe; the rod n is elongated below the ear, and connected to one arm of a lever m, having its fulcrum in a stand-

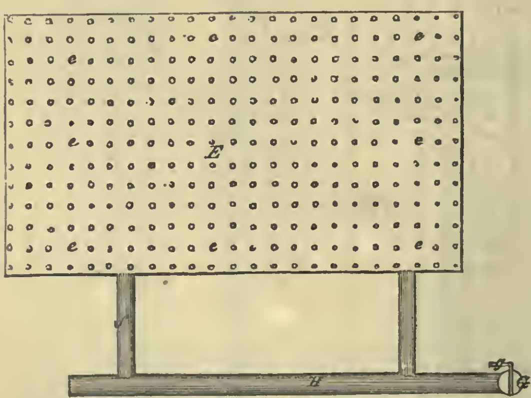
ard *o*, and having two arms of equal length, the opposite arm being connected by a rod *p*, to the arm of the lever to which the throttle-valve is connected. A spring *q* secured to the frame which carries the aprons A A and B B, always bears under the end of the lever-arm *i* and keeps it raised, causing the

1622.

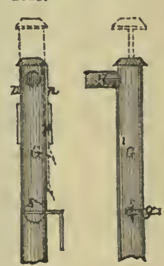


rod *p* to raise the end of the lever *m* to which it is attached, and throw down the opposite end causing the rod *n′* to close the valve *l* until it is opened by the means hereafter shown in the description of the operation of the machine. The throttle-valve S is so arranged that it is always open when the valve *l* is closed, so as to leave a free communication from the box E through the pipes *f f*, H G, to the box F containing the fan, or to any apparatus that may be employed for producing a vacuum. I is a toothed wheel on the doffer-shaft, through which the doffer receives its motion; it carries a small stud *r* on its outer face, which, during the revolution of the wheel, strikes the arm *k* of the lever *i k*; *a t* is a flap composed of a flat board or plate of the whole width of the doffer; it is hung on pivots or hinges *v v* on each side of the frame, and also has a lever *w* attached to one end which is struck by a pin *x* on the end of the doffer once during its revolution, so as to throw up the flap suddenly towards the apron B B.

1624.



1625. 1626.



The operation of the machinery, except as far as the mode of confining the weft below the apron is considered, is the same as in other machines employed for the same purpose, therefore I will proceed to describe the manner in which the weft is controlled.

The fan or other apparatus for producing the vacuum must be constant in its operation, so as to keep a constant draught or rush of air through the apron in the box E. The doffer makes one revolution for every sheet of weft that is formed; and therefore must correspond in diameter with the width of the warp. The warp travels a distance equal to the width of the weft during the time the weft is travelling across its upper face. The motion of both aprons is continuous, and the carding is taken from the doffer in the usual manner, from whence it proceeds to the under surface of the apron, where it is confined by the pressure of the atmosphere.

The speed of the apron B B is such as to take a sheet of carding produced by one revolution of the doffer D and carry it to a proper position for depositing on the warp during the time the warp moves a distance equal to the width of the weft. There is a space left in the cards on the doffer which causes a break in the carding when a sheet is formed of the proper length, and as soon as this space comes opposite the apron, the pin *r* on the wheel, strikes the arm *k*, and throws down the arm *i* of the lever *i k*, to the position shown in fig. 1620, the rod *h* instantly closes the throttle-valve S, and closes the communication with the apparatus producing the vacuum, and the rod *p* acting on the lever *m* causes the rod *n′* to open the valve *l*, both valves being actuated simultaneously; thus the sheet is thrown from

the apron B B suddenly, and deposited on the warp by the sudden current of air which rushes through the top of the pipe G, escaping through the bottom of the box E, and through the apron. The valves remain in the position last shown but an instant, or a very short space of time, for as soon as the pin *r* passes the arm *k*, the spring *p* raises the arm *i* and brings the valves to the position first described, the air entering the vacuum-box E through the apron B B; the space in the doffer on which there are no cards, having then passed the take-off, the carding or web again commences being given off from the doffer, and the end falls to the flap *t*; just at this moment the pin *x* strikes the lever *w* and throws up the flap, throwing the carding up to the apron where it is retained, and the operation proceeds as before described, the flap falling after the pin *x* passes the lever. This mode of carrying webs may be employed effectually for any fibrous material, and will be found advantageous from its not injuring, perforating, or tearing it.

FELTING. The process of blending or matting different kinds of fur or wool into a compact texture. See HAT MANUFACTURE.

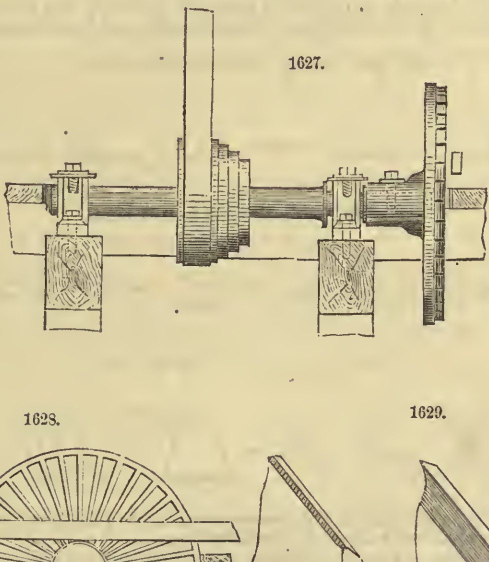
* FILES. The file is a strip or bar of steel, the surface of which is cut into fine points or teeth, that act by a species of cutting, closely allied to abrasion.

Files are almost endless in variety; and there is some four, five, or six features in every file, to adapt the instrument to the several kinds of work for which the file is used. Most of the names of files express these different features; for instance, the three following files are in common use:—

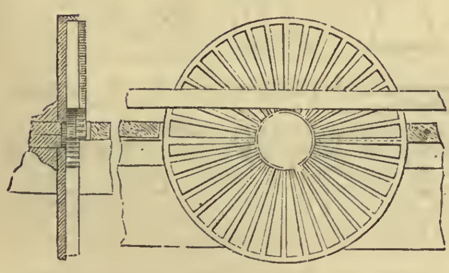
6 inch,	blunt,	single-cut,	saw file.
9 inch,	taper,	smooth,	half-round file.
12 inch,	parallel,	rough,	cotter file.

The watchmaker frequently uses files not exceeding three-quarters of an inch in length; mathemati-

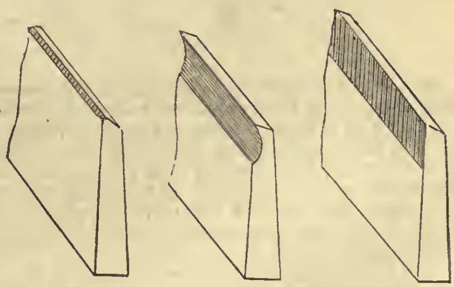
1627.



1628.



1629.



FILE. Cocker's Circular File, so called, is in reality a shaping machine on a small scale; the peculiarity being that instead of a row cutter, a series of distinct cutters are fitted into a disc, whence they can be easily removed to be sharpened on a grind stone. Fig. 1627 is a side elevation, showing the disc without the cutters. Fig. 1628 is a front view and section of the disc, the upper half showing the cutters, with the rings inside and outside, which hold them in position; and the lower half, the disc and grooves, without the cutters and rings. Fig 1629 are the various kinds of cutters used full size.

* Holtzapfel's Turning and Mechanical Manipulation.

cal instrument makers and gunmakers employ files from about 4 to 14 inches long; and machinists and engineers commonly require files from about 8 to 20 inches long, and sometimes use those of two and three feet and upwards in length.

Almost all files are required to be as straight as possible in their central line, and are distinguished as taper, blunt, and parallel files; a very insignificant number of files are made curvilinear in their central line, as in the rifllers used by sculptors and carvers, and some other files.

Many files that are in all other respects alike, differ in the forms and sizes of their teeth. Three forms of teeth are made, those of *double-cut* files, those of *floats*, or *single-cut* files, and those of *rasps*. The floats and rasps are scarcely used but for the woods and soft materials; the double-cut files are used for the metals and general purposes.

In a double-cut file, the thousands of points or teeth occur from *two* series of straight chisel-cuts crossing each other; in a single-cut file or float, the ridges occur from the *one* series of chisel-cuts, which are generally square across the float; and in a rasp the detached teeth are made by solitary indentations of a pointed chisel or punch.

Double-cut files are made of several gradations of coarseness, and which are thus respectively named:—

1. Rough.	1. Rough.
2. Middle-cut.	2. Bastard.
3. Bastard.	3. Second-cut.
4. Second-cut.	4. Smooth.
5. Smooth.	5. Dead-smooth.
6. Superfine.	

Some files have one or more edges that are left uncut, and these are known as *safe-edges*, because such edges are not liable to act upon those parts of the work against which they are allowed to rub, for the purpose of guiding the instrument. Occasionally the edges alone of files are cut, and the sides are left safe or smooth, as in some warding files, which nearly resemble saws.

The names of files are often derived from their purposes, as in saw-files, slitting, warding, and cotter files: the names of others from their sections, as square, round, and half-round files.

Fig. 1620. Sections derived from the Square.

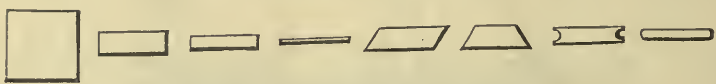


Fig. 1621. Sections derived from the Circle.

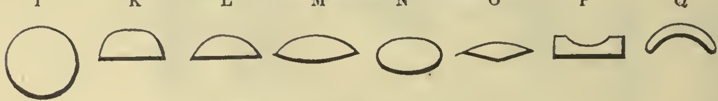


Fig. 1622. Sections derived from the Triangle.

Files of all the sections represented in the groups, Figs. 1620 to 1622, are more or less employed, although many of them are almost restricted to particular purposes.

Taper files, or *taper flat files*, are made of various lengths from about 4 to 24 inches, and are rectangular in section as in B, Fig. 1620; they are considerably rounded on their edges, and a little also in their thickness; their greatest section being towards the middle of their length or a little nearer to the handle, whence these files are technically known to be "bellied;" they are cut both on their faces and edges with teeth of four varieties; namely, rough, bastard, second-cut, and smooth-cut teeth. Taper flat files are in extremely general use amongst smiths and mechanics, for a great variety of ordinary works.

Hand files or *flat files* resemble the above in length, section, and teeth, but the hand files are nearly parallel in width, and somewhat less taper in thickness than the foregoing. Engineers, machinists, mathematical instrument makers, and others, give the preference to the hand file for flat surfaces and most other works.

Cotter files are always narrower than hand files of the same length and thickness; they are nearly flat on the sides and edges, so as to present almost the same section at every part of their length, in which respect they vary from 6 to 22 inches. Cotter files are mostly used in filing grooves for the cotters, keys, or wedges used in fixing wheels on their shafts, whence their name.

Pillar files also somewhat resemble the hand files, but they are much narrower, somewhat thinner, as in C, and are used for more slender purposes, or for completing works that have been commenced with the hand files. Pillar files have commonly one safe edge, and vary from 3 to 10 inches in length.

Half-round files are nearly of the section L, notwithstanding that the name implies the semicircular section; in general the curvature only equals the fourth to the twelfth part of the circle.

Triangular files are of the section R, and from 2 to 16 inches long; they are used for internal angles more acute than the rectangle, and also for clearing out square corners.

Cross files, or crossing files, are of the section M, or circular on both faces, but of two different curvatures.

Round files, of the section I, range from the length of 2 to 18 inches; they are in general taper, and much used for enlarging round holes.

Square files measure in general from 2 to 18 inches in length, and are mostly taper.

Equalling files are files of the section D. In width they are more frequently parallel than taper; in thickness they are always parallel. They are in general cut on all faces, and range from 2 to 10 inches long.

Knife files are of the section T, and in general very acute on the edge, they are made from 2 to 7 inches long, and are as frequently parallel as taper.

Slitting files, called also *feather-edged files*, resemble the last in construction and purpose, except in having, as in section V, two thin edges instead of one: they are almost always parallel.

Rubbers are strong heavy files, generally made of an inferior kind of steel; they measure from 12 to 18 inches long, from ¾ to 2 inches on every side, and are made very convex: they are frequently designated by their weight alone, which varies from about 4 to 15 lbs. Rubbers are nearly restricted to the square and triangular sections A and R. Some few rubbers are made nearly square in section, but with one side rounded, as if the sections K and B were united: these are called *half-thick*.

Many artisans, and more particularly the watchmakers, require other files than those described, and it is therefore proposed to add the names of some of the files to which the sections refer, premising that such names as are printed in *Italics* designate small files especially used in watchmaking.

Names of some of the Files corresponding with the Sections A to Z, (represented by Figs. 1620 *to* 1622.)

A.—Square files, both parallel and taper, some with one safe side; also square rubbers.

B.—When large, cotter files; when small, *verge* and *pivot* files.

C.—Hand files, parallel and flat files; when small, *pottance files*; when narrow, pillar files; to these nearly parallel files are to be added the taper flat files.

D.—When parallel, equalling *clock-pinion* and *endless-screw* files; when taper, slitting, entering, warding, and *barrel-hole* files.

E.—*French pivot and shouldering files*, which are small, stout, and have safe-edges; when made of large size, and right and left, they are sometimes called parallel V files, from their suitability to the hollow V V's of machinery.

F.—Name and purpose similar to the last.

G.—Flat file with hollow edges, principally used as a nail file for the dressing-case.

H.—Pointing mill-saw file, round-edge equalling file, and round-edge joint file; all are made both parallel and taper.

I.—Round file, gulleting saw file, made both parallel and taper.

K.—Frame saw file for gullet teeth.

L.—Half-round file. *Nicking* and *piercing* files, also cabinet floats and rasps; all these are usually taper. Files of this section which are small, parallel, and have the convex side uncut, and have also a pivot at the end opposite the tang, are called *round-off files*.

M.—Cross, or crossing files, also called double half-rounds.

N.—Oval files; oval gulleting files for large saws, called by the French *limes à double dos. Oval-dial file* when small.

O.—*Balance-wheel* or *swing-wheel files*, the convex side cut, the angular sides safe.

P.—Swaged files, for finishing brass mouldings; sometimes the hollow and fillets are all cut.

Q.—The curvilinear file.

R.—Triangular, three-square, and saw files, also triangular rubbers, which are cut on all sides.

S.—Cant file, probably named from its suitability to filing the insides of spanners, for hexagonal and octagonal nuts, or as these are generally called, six or eight *canted* bolts and nuts; the cant files are cut on all sides.

T.—When parallel, *flat-dovetail*, *banking*, and *watch-pinion* files; when taper, knife-edge files. With the wide edge round and safe, files of the section T are known as moulding files and *clock-pinion* files.

V.—Screw-head files, feather-edged files, *clock* and *watch-slitting* files.

W.—Is sometimes used by engineers in finishing small grooves and key ways, and is called a valve file, from one of its applications.

X.—A file compounded of the triangular and half-round file, and stronger than the latter; similar files with three rounded faces have also been made for engineers.

Y.—Double or checkering files, used by cutlers, gunmakers, and others. The files are made separately and riveted together, with the edge of the one before that of the other, in order to give the equality of distance and parallelism of checkered works, just as in the double saws for cutting the teeth of racks and combs.

Z.—Double file, made of two flat files fixed together in a wood or metal stock; this was invented for filing lead pencils to a fine conical point.

The manufacture of files.—The pieces of steel, or the blanks intended for files, are forged out of bars of steel that have been either tilted or rolled as nearly as possible to the sections required, so as to leave but little to be done at the forge; the blanks are afterwards annealed with great caution, so that in neither of the processes the temperature known as the blood-red heat may be exceeded. The surfaces of the blanks are now rendered accurate in form and quite clean in surface either by filing

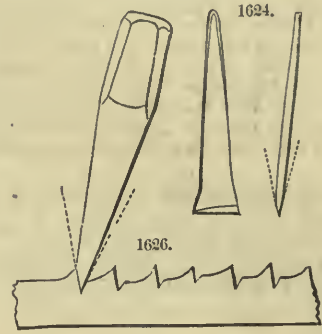
or grinding. For the smaller files the blanks are mostly filed into shape as the more exact method; for the larger, the blanks are more commonly ground on large grindstones as the more expeditious method; in some few cases the blanks are planed in the planing machine, for those called *dead-parallel files.* The blank before being cut is slightly greased, that the chisel may slip freely over it.

The file-cutter is seated before a square stake or anvil, and places the blank straight before him, with the tang towards his person; the ends of the blank are fixed down by two leather straps or loops, one of which is held fast by each foot.

The largest and smallest chisels commonly used in cutting files are represented in two views; and half size in Figs. 1623 and 1624. The first is a chisel for large rough files; the length is about 3 inches, the width 2¼ inches, and the angle of the edge about 50 degrees; the edge is perfectly straight, but the one bevel is a little more inclined than the other, and the keenness of the edge is rounded off, the object being to indent, rather than cut the steel; this chisel requires a hammer of about 7 or 8 lbs. weight. Fig. 1624 is the chisel used for small superfine files; its length is 2 inches, the width ½ inch;

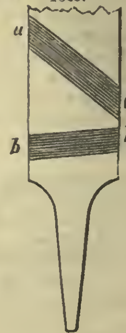
1623.

1624.



1626.

1625.



it is very thin, and sharpened at about the angle of 35 degrees; the edge is also rounded, but in a smaller degree: it is used with a hammer weighing only one to two ounces, as it will be seen the weight of the blow mainly determines the distance between the teeth. Other chisels are made of intermediate proportions, but the width of the edge always exceeds that of the file to be cut.

The first cut is made at the point of the file; the chisel is held in the left hand, at a horizontal angle of about 55 degrees, with the central line of the file, as at *a a*, Fig. 1625, and with a vertical inclination of about 12 to 4 degrees from the perpendicular, as represented in the figures 1623 and 1624 supposing the tang of the file to be on the left-hand side. The following are nearly the usual angles for the vertical inclination of the chisels; namely, for rough rasps, 15 degrees beyond the perpendicular, rough files, 12 degrees; bastard files, 10 degrees; second-cut files, 7 degrees; smooth-cut files, 5 degrees; and dead-smooth-cut files, 4 degrees. The blow of the hammer upon the chisel causes the latter to indent and slightly to drive forward the steel, thereby throwing up a trifling ridge or *burr*; the chisel is immediately replaced on the blank, and slid from the operator until it encounters the ridge previously thrown up, which arrests the chisel or prevents it from slipping further back, and thereby determines the succeeding position of the chisel. The chisel having been placed in its second position is again struck with the hammer, which is made to give the blows as nearly as possible of uniform strength and the process is repeated with considerable rapidity and regularity, 60 to 80 cuts being made in one minute, until the entire length of the file has been cut with inclined, parallel, and equidistant ridges, which are collectively denominated the *first course.* So far as this one face is concerned, the file, if intended to be single-cut, would be then ready for hardening; and when greatly enlarged, its section would be somewhat as in Fig. 1626. The teeth of some single-cut files are much less inclined than 55 degrees; those of floats are in general square across the instrument.

Most files, however, are double cut, or have two series or *courses* of chisel cuts, and for these the surface of the file is now smoothed by passing a smooth file once or twice along the face of the teeth, to remove only so much of the roughness as would obstruct the chisel from sliding along the face in receiving its successive positions, and the file is again greased.

The second course of teeth is now cut, the chisel being inclined vertically as before, or at about 12 degrees, but horizontally, about 5 to 10 degrees from the rectangle, as at *b b*, Fig. 1625; the blows are now given a little less strongly, so as barely to penetrate to the bottom of the first cuts, and consequently the second course of cuts is somewhat finer than the first. The two series of courses fill the surface of the file with teeth which are inclined towards the point of the file, and that when highly magnified much resemble in character the points of cutting tools generally, as seen in Fig. 1626.

If the file is flat and to be cut on two faces, it is now turned over; but to protect the teeth from the hard face of the anvil, a thin plate of pewter is interposed. Triangular and other files require blocks of lead having grooves of the appropriate sections to support the blanks, so that the surface to be cut may be placed horizontally. Taper files require the teeth to be somewhat finer towards the point, to avoid the risk of the blank being weakened or broken in the act of its being cut, which might occur if as much force were used in cutting the teeth at the point of the file, as in those at its central and stronger part.

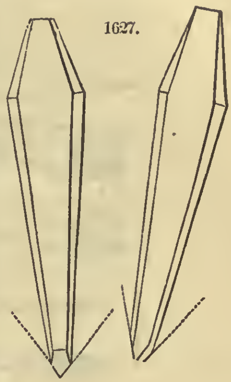
Eight courses of cuts are required to complete a double-cut rectangular file that is cut on all faces, but eight, ten, or even more courses are required in cutting only the *one* rounded face of a half-round

file. There are various objections to employing chisels with concave edges, and therefore in cutting round and half-round files the ordinary straight chisel is used and applied as a tangent to the curve. It will be found that in a smooth half-round file one inch in width, that about twenty courses are required for the convex side, and two courses alone serve for the flat side. In some of the double-cut gullet-tooth saw files, of the section K, as many as twenty-three courses are sometimes used for the convex face, and but two for the flat. The same difficulty occurs in a round file, and the surfaces of curvilinear files do not therefore present, under ordinary circumstances, the same uniformity as those of flat files.

Hollowed files are rarely used in the arts, and when required it usually becomes imperative to mploy a round-edged chisel, and to cut the file with a single course of teeth.

The teeth of rasps are cut with a punch, which is represented in two views, Fig. 1627. The punch for a fine cabinet rasp is about $3\frac{1}{2}$ inches long, and $\frac{5}{8}$ square at its widest part. Viewed in front, the two sides of the point meet at an angle of about 60 degrees: viewed edgeways, or in profile, the edge forms an angle of about 50 degrees, the one-face being only a little inclined to the body of the tool.

1627.



In cutting rasps, the punch is sloped rather more from the operator than the chisel in cutting files, but the distance between the teeth of the rasp cannot be determined as in the file, by placing the punch in contact with the burr of the tooth previously made. By dint of habit, the workman moves or, technically, *hops* the punch the required distance; to facilitate this movement, he places a piece of woollen cloth under his left hand, which prevents his hand coming immediately in contact with, and adhering to the anvil.

The teeth of rasps are cut in rather an arbitrary manner, and to suit the whims rather than the necessities of the workmen who use them. Thus the lines of teeth in cabinet rasps, wood rasps, and farriers' rasps, are cut in lines sloping from the left down to the right hand side; the teeth of rasps for boot and shoe last makers and some others, are sloped the reverse way; and rasps for gun-stockers and saddle-tree makers are cut in circular lines or crescent form. These directions are quite immaterial; but it is important that every succeeding tooth should cross its predecessor, or be intermediate to the two before it; as if the teeth followed one another in right lines, they would produce furrows in the work, and not comparatively smooth surfaces.

In cutting files and rasps they almost always become more or less bent, and there would be danger of breaking them if they were set straight whilst cold; they are consequently straightened whilst they are at the red heat, immediately prior to their being hardened and tempered.

Previously to their being hardened, the files are drawn through beer grounds, yeast, or other sticky matter, and then through common salt, mixed with cow's hoof previously roasted and pounded, and which serve as a defence to protect the delicate teeth of the file from the direct action of the fire. The compound likewise serves as an index of the temperature, as on the fusion of the salt, the hardening heat is attained; the defence also lessens the disposition of the files to crack or clink on being immersed in the water.

The file, after having been smeared over as above, is gradually heated to a dull red, and is then mostly straightened with a leaden hammer on two small blocks also of lead; the temperature of the file is afterwards increased until the salt on its surface just fuses, when the file is immediately dipped in water. The file is immersed, quickly or slowly, vertically or obliquely, according to its form; that mode being adopted for each variety of file which is considered best calculated to keep it straight.

It is well-known that from the unsymmetrical section of the half-round file, it is disposed, on being immersed, to become hollow or bowed on the convex side, and this tendency is compensated for by curving the file whilst soft in a nearly equal degree in the reverse direction.

It nevertheless commonly happens, that with every precaution the file becomes more or less bent in hardening, and if so, it is straightened by pressure, either before it is quite cold, or else after it has been partially reheated. The pressure is variously applied, sometimes by passing one end of the file under a hook, supporting the centre on a prop of lead, and bearing down the opposite end of the file; at other times by using a support at each end, and applying pressure in the middle, by means of a lever, the end of which is hooked to the bench. Large files are always straightened before they are quite cooled after the hardening, and whilst the central part retains a considerable degree of heat. When straightened, the file is cooled in oil, which saves the teeth from becoming rusty.

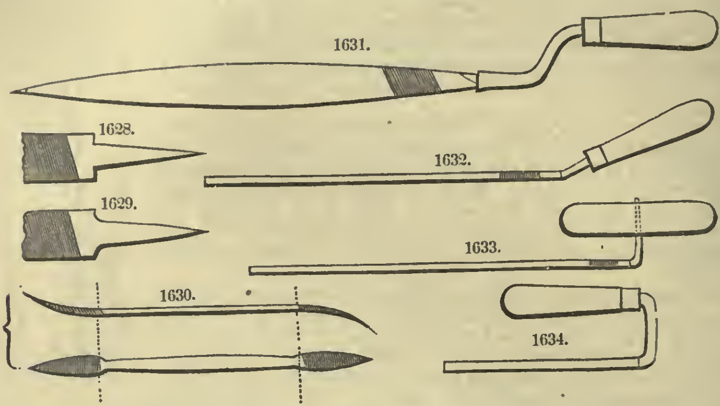
The tangs are now softened to prevent their fracture; this is done either by grasping the tang in a pair of heated tongs, or by means of a bath of lead contained in an iron vessel with a perforated cover, through the holes in which the tangs are immersed in the melted lead that is heated to the proper degree. The tang is afterwards cooled in oil, and when the file has been wiped and the teeth brushed clean, it is considered fit for use.

The superiority of the file will be found to depend on four points,—the primary excellence of the steel—the proper forging and annealing without excess of heat—the correct formation of the teeth—and the success of the hardening.

Means of grasping the file.—In general, the end of the file is forged simply into a taper tang or spike, for the purpose of fixing it in its wooden handle, but wide files require that the tang should be reduced in width, either as in Fig. 1628 or 1629. The former mode, especially in large files, is apt to cripple the steel and dispose the tang to break off, after which the file is nearly useless. The curvilinear tang, Fig. 1629, is far less open to this objection. Some workmen make the tangs of large files red-hot, that they may burn their own recesses in the handles, but this is objectionable, as the charred wood is apt to crumble away and release the file. It is more proper to form the cavity in the handle with coarse floats made for the purpose.

In driving large files into their handles it is usual to place the point of the file in the hollow behind the chaps of the tail vice, and to drive on the handle with a mallet or hammer. Smaller files are fixed obliquely in the jaws of the vice, between clamps of sheet brass, to prevent the teeth either of the vice or file from being injured, and the handle is then driven on.

In the double-ended rifflers, or bent files, Fig. 1630, and in some other files, there is a plain part in the middle, fulfilling the office of a handle; and in several of the files and rasps made for dentists, farriers, and shoemakers, the tool is also double, but without any intermediate plain part, so that the one end serves as the handle for the other.



In general, the length of the file exceeds that of the object filed, but in filing large surfaces it becomes occasionally necessary to attach cranked handles to the large files or rubbers, as in Fig. 1631, in order to raise the hand above the plane of the work. Sometimes the end of the file is simply inclined, as in Fig. 1632, or bent at right angles, as in Fig. 1633, for the attachment of the wooden handles represented; but the last two modes prevent the second side of the file from being used, until the tang is bent the reverse way. The necessity for bending the file is avoided by employing as a handle a piece of round iron, $\frac{5}{8}$ or $\frac{3}{4}$ inch in diameter, bent into the semicircular form as an arch, the one extremity (or abutment) of which is filed with a taper groove to fit the tang of the file, whilst the opposite end is flat, and rests upon the teeth; in this manner both sides of the file may be used without any preparation.

Fig. 1634 represents, in profile, a broad and short rasp with fine teeth, used by iron-founders in smoothing off loam moulds for iron castings; this is mostly used on large surfaces, to which the ordinary handle would be inapplicable, and the same kind of tool when made with coarser teeth, will be recognized as the baker's rasp.

Cabinet-makers sometimes fix the file to a block of wood to serve for the grasp, and use it as a plane. Thus mounted, the file may also be very conveniently used on a shooting-board, in filing the edges of plates to be inlaid.

1635.

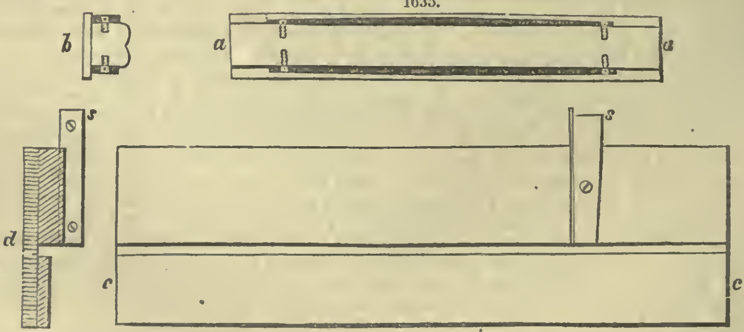
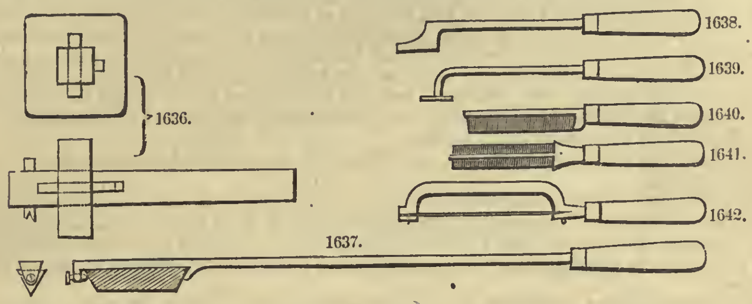


Fig. 1635 represents a very good arrangement of this kind. *a a* is the plan, and *b* the section of the file stock, *c c* is the plan of the shooting-board, and *d* its section. Two files (that are represented black) are screwed against the sides of a straight bar of wood, which has also a wooden sole or bottom plate, that projects beyond the files, so that the smooth edge of the sole may touch the shooting-board instead of the file teeth. The shooting-board is made in three pieces, so as to form a groove to receive the file dust, which would otherwise get under the stock of the file. The shooting-board has also a wooden stop *s*, faced with steel, that is wedged and screwed into a groove made across the top piece, and the stop being exactly at right angles, serves also to assist in squaring the edges of plates or the ends of long bars, with accuracy and expedition.

Short pieces of files (or tools as nearly allied to saws) are occasionally fixed in the ends of wooden

stocks, in all other respects like the routing gages of carpenters, as seen in two views in Fig. 1636. The coopers' *croze* is a tool of this description.

Files intended for finishing the grooves in the edges of slides, are sometimes made of short pieces of steel of the proper section, (see Fig. 1637,) cut on the surfaces with file teeth, and attached in various ways to slender rods or wires, serving as the handles, and extending beyond the ends of the slides: or the handle is at right angles to the file, and formed at the end, as a staple, to clip the ends of the short file, as in reaching the bottom of a cavity. Files intended to reach to the bottom of shallow cavities are also constructed as in Figs. 1638 and 1639, or sometimes an inch or more of the end of an ordinary file is bent some 20 or 30 degrees, that the remainder may clear the margin of the recess.

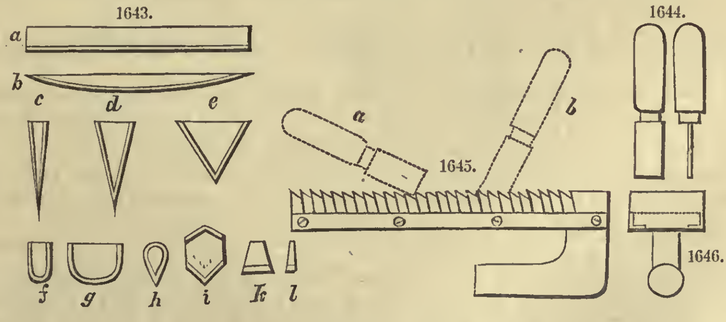


To stiffen slender files, they are occasionally made with tin or brass backs, as in Figs. 1640 and 1641; such are called dovetail files; and thin equalling files are sometimes grasped in a brass frame, Fig. 1642, exactly like that used for a metal frame-saw.

Notwithstanding the great diversity in the files already alluded to, it is to be remarked that all those hitherto noticed are made entirely of steel, and their teeth are all produced in the ordinary manner by means of the chisel and hand hammer. It now remains to notice a few of the less usual kinds of rasps, floats, and files, the teeth of which are, for the most part, produced by means differing from those already described.

The rifflers, Fig. 1630, used by sculptors, are required to be of numerous curvatures, to adapt them to the varying contour of works in marble. In general the rifflers are made of steel in the ordinary mode, but they have also been made of wrought-iron, and slightly case-hardened, in which case the points of the teeth become converted into steel, but the general bulk of the instrument remains in its original state as soft iron; consequently such case-hardened rifflers admit of being bent upon a block of lead with a leaden mallet, so that the artist is enabled to modify their curvatures as circumstances may require.

Several kinds of floats are made with coarse, shallow, and sharp teeth; these teeth could not be cut with the chisel and hammer in the ordinary manner, but are made with a triangular file. Figs. *a* to *l*, 1643, represent the sections of several of these floats, which have teeth at the parts indicated by the double lines; for instance, *a* is the float, *b* the *graille*, *c* the *found*, *d* the *carlet*, *e* the *topper*, used by the horn and tortoiseshell comb-makers. The floats *f* to *i* are used by ivory carvers for the handles of knives, and in the preparation of works, the carving of which is to be completed by scorpers and gravers; *k* and *l* are used in inlaying tools in their handles; *k* is made of various widths, and is generally thin, long, and taper; *l* is more like a key-hole saw.



The larger of the floats, such as those *a* to *e*, used by the comb-makers, are kept in order principally by the aid of a burnisher, represented in two views in Fig. 1644; the blade is about 2 inches long, 1 inch wide, and 1-16th thick; the end is mostly used, and which is forcibly rubbed, first on the front edge of every tooth, as at *a*, Fig. 1645, and then on the back, as at *b*, by which means a slight burr is thrown up on every tooth, somewhat like that on the joiner's scraper; but in this art the burnisher is commonly named a *turn file*.

The *quannet* is a float resembling Fig. 1634, but having coarse filed teeth, of the kind just described; it may be considered as the ordinary flat file of the horn and tortoiseshell comb-makers, and in using the quannet, the work is mostly laid upon the knee as a support. An ingenious artisan in this branch, Mr. Michael Kelly, invented the quannet represented in Figs. 1645 and 1646. The stock consists of a piece of beach-wood, in which, at intervals of about one-quarter of an inch, cuts inclined nearly 30 degrees with the face, are made with a thin saw; every cut is filed with a piece of saw-plate. The edges of the plates and wood are originally filed into the regular float-like form, and the burnisher is subsequently resorted to as usual. The main advantage results from the small quantity of steel it is necessary to operate upon, when the instrument requires to be restored with the file. From this circumstance, and also from its less weight, the wooden quannet, Fig. 1645, is made of nearly twice the width of the steel instrument, Fig. 1634, and the face is slightly rounded, the teeth being sometimes inserted square across, as in a float, at other times inclined some 30 degrees, as in a single-cut file.

The cutting of files by machinery.—The practical introduction of machinery for cutting files appears to be due to a Frenchman of the name of Raoul, at about the close of the last century, but the description of the machine has not been published, and the manufacture is now carried on by his son. His files are beautiful specimens of workmanship, being more strictly regular, and also less liable to clog or pin when in use, than files cut by hand, as usual.

His manufacture is principally limited to watch files with flat sides, and measuring from ¾ of an inch to 5 or 6 inches long.

Machines have been recently constructed in England for cutting both large and small files, and half a dozen or more at a time. The details of the machines display great ingenuity and skill, but there are various drawbacks that prevent, under ordinary circumstances, any great commercial advantage in the machine over the hand process, from which considerations the patent file-cutting machines are not at present used.

We give drawings and a description of a recently invented file machine, patented in 1847 by George Winslow, of Boston. We know not how far it has been successful, but it is well worthy of notice as an example of ingenious combinations, and to illustrate what has been done in this department of mechanism.

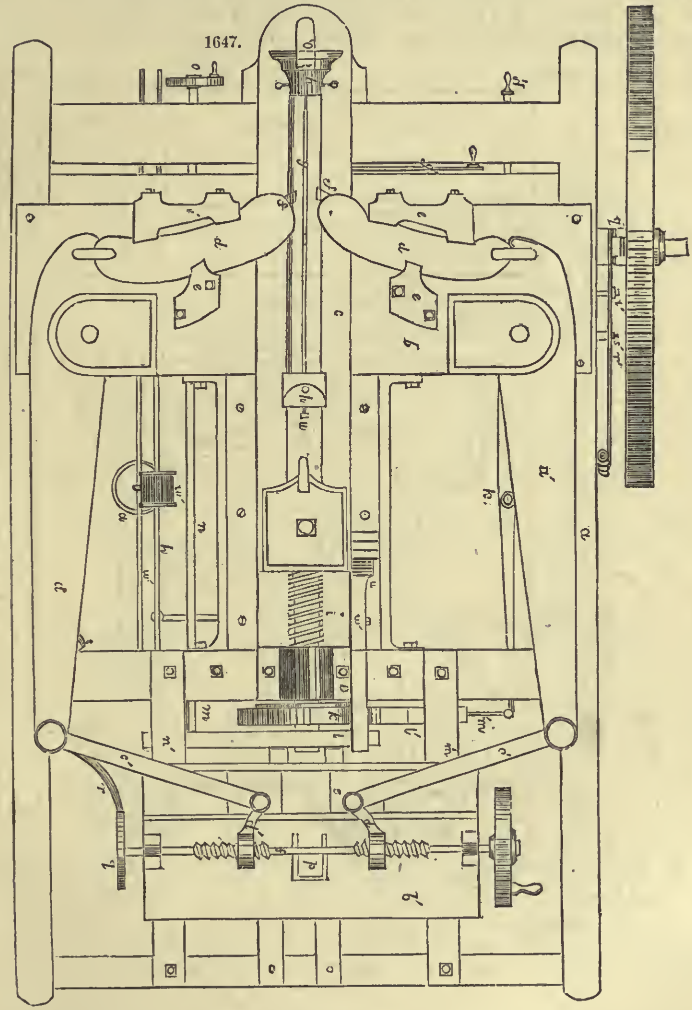
FILE AND RASP MACHINE. Fig. 1647 represents a plan view of this apparatus or machinery, as laid down by the patentee, in the drawing attached to the specification; and Fig. 1648 is a side elevation of the same. It consists of a rectangular framework *a a*, which may be of wood or other suitable material; stretched across this framework is a plate *b*, on which are two levers a' a', disposed on either side of the machine and moving on fulcra a''' a'''; the long ends of these levers are connected to a sort of toggle d', by means of the straps c', and the short ends are connected by links to the blocks or chisel-holders *d d*; the chisel-holders move on the plate *b*, and are guided by the brackets *e e e e*, and though constrained to move in a particular direction, are free to turn round, so that the chisels *f f* may be adjusted to any angle at which it may be required to form the indentations or teeth on the blank *g*. This is supported between two poppets *h h*, the one receiving the shank or tang in a socket, in which it is secured by binding screws, and the other is supported by a centre, received by an indentation made in the end of the blank. It will be observed that a tooth on each side of the blank is produced at the same time, the pressure of one chisel sustaining the opposing force of the other, the poppets *h h* being so fitted to their support *j* as to admit of a movement in a transverse direction, to allow for any inequality in the surface of the blank *g*; *j* is a slide, which is fitted between dovetailed grooves, so as to admit of sliding in a longitudinal direction. This slide forms the immediate support for the blank, and is strengthened by an arch-piece p', as seen at Fig. 1648. This slide is caused to travel by means of a screw *i*, which passes through a nut attached to the bottom of the slide. A plate b' is fitted on two longitudinal slides n' n'. This plate receives a reciprocating motion from the main driving-shaft, through the intervention of the connecting-rod a'', and upright lever *p*. The driving-shaft is furnished with a disk or plate *x*, having a radial slot cut therein, in which the crank pin can be adjusted, so as to vary the throw, and consequently the motion of the connecting-rod a''. This rod is also adjustable in the vertical lever *p*, so as to bring the connection nearer to, or further from, the fulcrum on which it moves. Each movement of this sliding plate b' produces a closing of the cutters *f f*, by reason of the movement of the toggles d' d', which are mounted on the plate b', and thus raise a tooth by forming an indentation in the blank.

Now in cutting files by this machine, it is necessary to begin the cut at the point or thinnest part of the file, when the greatest range of movement is given to the plate b'; and as the cutting proceeds towards the thick part of the blank, the movement of the plate b' must decrease, imparting less movement to the levers a' a'; and consequently the cutters will not be brought so close together; but in reducing this movement of the plate, the angle formed by the levers c' c' will be less, and consequently their power will decrease also, but which is compensated for by an apparatus hereafter explained. As the cutters always close at the same point, it is necessary that the blank should move a sufficient distance at each closing thereof to allow for the formation of another tooth; this is effected by partially turning the screw *i* which moves the carriage or slide *j*, which is performed as follows:—

A spur-wheel *k* is mounted on the end of the screw *i* which projects through the bearing; this is not fixed to the screw, but is allowed to revolve freely thereon, and is furnished with a click pivoted to the side thereof; this takes into a ratchet affixed to the screw, and therefore as the wheel is turned in one direction it will carry the screw round with it, but on a reverse motion taking place the click will slip the teeth of the ratchet; the screw *i* at the same time remaining stationary. The wheel *k* has this motion communicated to it by means of a vertical rack-bar l', being connected by a rod c'' to a bell-crank b'', the pendent arm of which is moved by contact of a pin placed in the connecting-rod a'', the reaction being produced by the weight of the rack-bar, the rise and fall of which may be varied by moving the position of the pin in the rod a''; thus may the number of indentations produced to a given length of the blank be regulated according to the requisite degree of fineness of the file.

The upper end of the rack-bar is connected by a rod m' to the hand lever h', which oscillates on a fixed fulcrum at k'; this arrangement being for the withdrawal of the teeth of the rack-bar, and thereby stop the movement of the screw i; but the movement of the hand lever h' at the same time withdraws the clutch q' from the fly-wheel, and therefore stopping simultaneously the entire action of the machine. The hand lever h' is connected by the rod s' to the clutch lever r'; this lever is also connected by a rod t' to a spring inside the framework, which maintains a permanent pull to withdraw the clutch, but which is counteracted by a catch on the end of a lever g'; this retains the lever h' in a position for work, which may be released by hand at pleasure, or the lever g' is tripped up by a projection x' on the under side of the slide j; at the completion of the teeth, this throws the restraint from the lever h', and the machine stops. A spur-wheel l is mounted on the screw i, which geers into another wheel m, placed on a longitudinal shaft n; this is turned by a hand-wheel o, and is for the purpose of working the slide i back, or otherwise adjusting its position before commencing the cut.

1647.

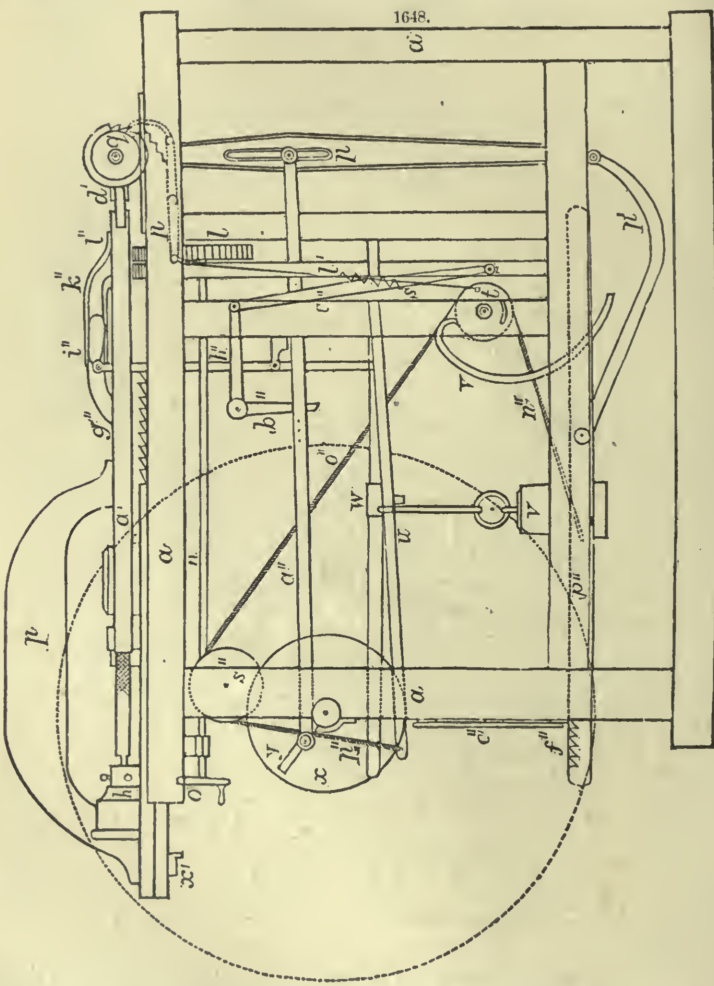


It will be seen by the general arrangement of the geer for moving the slide b', that if the fulcrum on which the vertical lever p moves were stationary, the space traversed by b' would be the same, but to allow it to recede as the thickness of the file increases, the lower end of the lever p is jointed to a bent lever p'', attached to a horizontal bar q''; this is fitted in bearings, so as to be capable of movement in a longitudinal direction, but restrained by the cord u'' with a certain amount of force, which when overcome by the force required for the cutters $f f$, the bar q'' recedes and is retained by a catch f'' falling into the teeth on the end of the said bar; by a complication of levers not seen in the cuts, this catch is raised at each revolution of the disk x, a pin fixed thereto actuating the levers before mentioned. The cord u'' is wound on a drum placed on the same shaft as the plate t'', and cam v''; this cam has a groove on its periphery, over which a cord c'' passes while the cutting is in progress; the cord being attached at one end to the smallest part of the cam v'', is carried thence, and wound on a drum s'', from

the opposite side, while another cord r'' supports the lever u, on which hangs the weight v. The force of this weight is therefore brought to bear on the cam v'', with the requisite degree of force to give the necessary tension to the cord u''; the cord c'', as it is gradually wound on the cam, gives, by reason of the leverage thereof, a greater amount of tension to the cord u'', in order to compensate for the loss of power of the progressive levers c' c', as their range of movement is removed nearer the end of the machine.

As a further compensation for this loss of power, the weight v, which is hung on the lever u, is gradually moved further from the fulcrum on which one end of this lever is supported, thus increasing the weight on the cord r'' which supports the other end thereof; this is arranged as follows: a bar t placed side by side of the lever u is fitted in slots, cut in the framing so as to move in a longitudinal direction, and is furnished with a sliding piece w, which can be in any position; this piece w has a projection which takes the suspending rod of the weight v, so that any movement imparted to the bar t is transmitted to the weight. A vertical lever h'' is pivoted to a fulcrum fixed to the framing; the lower end of this lever is again connected to a horizontal lever (not seen in the cuts) in such manner as to multiply the movement which is communicated to the bar t. The upper or driving end of the lever h'' is

1648.



furnished with a pawl g'', pivoted about the middle of its length; one end of the lever falls into the teeth of a rack v', affixed to the sliding carriage j, and the other has a stud pin which traverses an irregular slot or guide l'', k'', i''; the motion imparted to the slide j is thus communicated by the pawl g'' to the lever h'', thence to the weight v, altering the position thereof gradually as the cutting progresses. This motion will continue so long as the stud pin of the pawl g'' continues to traverse the horizontal portion of the guide from i'' to k'', which will occupy the time necessary for cutting the tapered part of the file, at the completion of which the stud pin will pass down the incline from k'' to l'', canting the other end of the pawl g'', consequently withdrawing it from the rack, and preventing any further movement of the weight on the lever u. the cutters $f\,f$ advancing within a uniform distance of each other after

that point. Two bearings are raised from the plate b' which support a shaft f'; this is furnished with two screws, one being what is termed a right and the other a left hand thread, corresponding with screws in the toggles d' d'; these are adjusted by the hand-wheel on the end of the shaft so as to suit the thickness of the first cut, commencing at the thinnest part of the blank g. This screw shaft is continued beyond the bearing at the opposite end from the hand-wheel, and furnished with a ratchet-wheel q; this is brought into action as the plate t'' and cam are gradually turned round, it being connected thereto by a spring s which depresses one end of a lever r, supported by the framing, the other end carrying a pawl, which, when sufficiently elevated by the action of the machine, will be brought into contact with the ratchet q, as it traverses backwards and forwards with the plate b', at each movement causing the ratchet to turn one tooth, thereby actuating the toggles d' d' in the requisite manner to form an additional compensation for the loss of power before mentioned in maintaining the requisite amount of advance of the cutters.

The patentee claims, first, the general arrangement of machinery or apparatus whereby the teeth of a file or rasp may be cut with great regularity, and on both sides of the said blank at one and the same time. Secondly, the combination of the cam with this machine, together with the increasing power of the weight for the purpose of keeping up a compensatory power for the loss occasioned by the decreasing obtuse angle formed by the progressive levers c' c', as the range of their advancing movement is restricted.

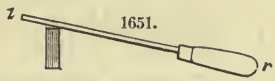
FILING. The use of the file is more difficult than that of the generality of mechanical tools, from the circumstance of the file possessing, in a very inferior degree, the *guide principle*, the influence of which principle, affects all tools, from the most simple cutting tool used by hand, to the most complex cutting machine or engine.

Commencing with the position of the work, it is in all cases desirable that the surface to be filed should be placed *horizontally*, and the general rule for the height of the work above the ground is, that the surface to be filed should be nearly level with the elbow joint of the workman. Some latitude is, however, required in respect to the magnitude of the works, as when they are massive, and much is to be filed off from them, it is desirable that the work should be a trifle lower than the elbow; when the work is minute and delicate, it should be somewhat higher, so that the eye may be the better able to add its scrutiny to that of the sense of feeling of the hand, upon which, principally, the successful practice depends.

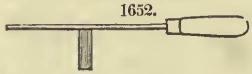
It is apparent that the most direct way of producing a flat surface with the file, would be to select a file the face of which was absolutely flat, and that should be moved in lines absolutely straight; but there are certain interferences that prevent these conditions being carried out. First, although it is desirable to employ files that are as nearly straight as possible, and that are also fixed straightly in their handles, yet very few files possess this exactitude of form, and although in the attempt to obtain this perfection, some files are planed before being cut with teeth, still the cutting and the hardening so far invalidate this practice, that few even of these planed files can retain their perfect straightness. Therefore, as it may be almost taken for granted that no files truly possess the intended form, it is better purposely to adopt that kind of irregularity, which the least interferes with the general use of the instrument.

1649.

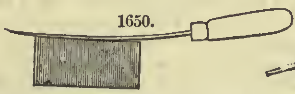
1651.



1652.



1650.



1653.

The file, if concave or hollow in respect to its length, in the manner coarsely exaggerated in Fig. 1649, might be used for works of corresponding *convexity;* but it would be impossible to file a flat surface therewith, as the concave file would only touch the surface at its edges, but the convex side of the same file might, as in Fig. 1650, be made to touch any and every part of the surface if moved in a right line. On this account most files are made thicker and wider in the middle, or with both faces convex, and the error of hardening will then rarely make either side concave, but will leave both faces convex, although differently so; and consequently, both sides, notwithstanding some irregularity, are usable upon flat works, provided the operator can move them in a right line across the work.

It might be urged that the file, from being itself in the form of the arc of a large circle, would reduce the work to the counterpart form; it is true this is the tendency, and may by dexterity become the result, even on narrow pieces; but the contrary error is more common, so that the surface of the work becomes rounded instead of concave or plane.

The file held in the two hands upon the narrow work, may be viewed as a double-ended lever, or as a scale-beam supported on a prop; and the variation in distance of the hands from the work or prop gives a disposition to rotate the file upon the work, and which is only counteracted by habit or experience.

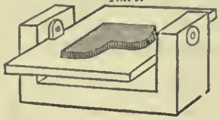
Assuming, for the moment, that in the three diagrams the vertical pressure of the right hand at r, and the left at l, to be in all cases alike, in Fig. 1651, or the beginning of the stroke, the right hand would, from acting at the longer end of the lever, become depressed; in Fig. 1652, or the central position, the hands would be in equilibrium and the file horizontal; and in Fig. 1653, or the end of the stroke,

the left hand would preponderate; the three positions would inevitably make the work round, in place of leaving it plane or flat.

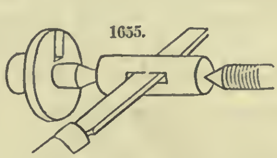
It is true the diagrams are extravagant, but this rolling action of the file upon the work is in most cases to be observed in the beginner; and those practised in the use of the file have, perhaps unconsciously, acquired the habit of pressing down *only* with the left hand at the commencement, and *only* with the right hand at the conclusion of every stroke; or negatively, that they have learned to avoid swaying down the file at either extreme, and which bad practice will necessarily result, if the operator have not at first a constant watch upon himself, to feel that the file and work are always in true contact, throughout the variable action of the hands upon the instrument.

The work, when small, is almost invariably held on the filing-block with the left hand, occasionally through the intervention of a hand-vice, Fig. 1657. In this case the two hands act in concert, the right in moving the file, the left in adjusting the position of the work, until the individual is conscious of the agreement in position of the two parts.

1654.



1655.



1656.

Sometimes indeed the partial rotation of the work, in order to adapt the work to the file, is especially provided for, so as to compensate for the accidental swaying of the file; such is the case in the various kinds of *swing tools*, used by watchmakers in filing and polishing small flat works. A similar end is more rarely obtained, on a larger scale, when the file is required to be held in both hands. For example, *filing-boards* resembling Fig. 1654, and upon which the work is placed, have been made to move on two pivots, somewhat as a gun moves on its trunnions; consequently the works, when laid upon the swinging board, assume the same angle as that at which the file may at the moment be held.

A more common case is to be seen in filing a rectangular mortise, through a cylindrical spindle, as in Fig. 1655; the hole is commenced by drilling three or four holes, which are thrown into one by a cross-cut chisel, or small round file; and the work, when nearly completed, is suspended between the centres of the lathe, so that it may freely assume the inclination of the file. At other times, the cylinder is laid in the interval between the edges of the jaws of the vice, that are opened as much as two-thirds the diameter of the object, which then similarly rotates on the supporting edges; this mode is shown in Fig. 1656.

These three applications are objectionable in some instances, as the file is left too much at liberty, and the works are liable to be filed hollow instead of flat, especially if the file be rounding, because the unstable position of the work prevents the file from being constrained to act on any particular spot that may require to be reduced.

After a file has been used for wrought-iron or steel, it is less adapted to filing cast-iron or brass, which require keen files; therefore to economize the wear of the instrument, it is used for a time on brass or cast-iron, and when partially worn, it is still available for filing wrought-iron or steel; whereas, had the file been first used on these harder materials, it would have been found comparatively ineffective for brass and cast-iron.

As a further measure of economy, the pressure on the file should be always relieved in the back stroke, which otherwise only tends to wear down or break off the tops of the teeth, as their formation shows that they can only cut in the ordinary or advancing stroke; the file should, in consequence, be nearly lifted from the work in drawing it back, but it is not usual actually to raise the file off the work, as it then becomes needful to wait an instant before the next stroke, to ensure the true position of the file upon the work being resumed; whereas, if it is brought back with inconsiderable pressure, the file is not injured, and the hand still retains the consciousness of the true contact of the file and work, without which the instrument is used with far less decision and correctness than it otherwise would be.

Some workmen smooth the work by the method called *draw-filing*, or by drawing the file sideways along the work, using it in fact as a spoke-shave instead of a file. Another mode sometimes employed is to curl the work with the file, by describing small circles with the instrument as in grinding or polishing, but neither of these practices employs the file teeth in the mode in which they are legitimately adapted to cut, and no great reliance should be placed upon them. When smooth surfaces are required, it is better, as the work advances towards completion, to select files that are gradually finer, but always to use them from point to heel.

When it is desired to make the smooth files cut wrought-iron, steel, and other *fibrous* metals very smoothly, the file is used with a little oil to lubricate the surface, so that it may not penetrate to the same degree as it would if used dry.

The particles removed from the materials operated upon, are always more or less liable to clog the file, but which, particularly when the instrument is dry, are partially removed by giving the edge of the file a moderately smart blow on the chaps of the vice or the edge of the bench; but particles of wrought-iron, steel, and other fibrous metals, are apt to *pin the file*, or to stick in so hard as to require to be picked out with a pointed steel wire, which is run through the furrow in which the pin is situated.

Files are sometimes cleaned with a *scratch-brush*, which is a cylindrical bundle of fine steel or brass wire, bound tightly in its central part, but allowing the ends of the wire to protrude at both extremities as a stiff brush. Occasionally also, a *scraper* is used, or a long strip of sheet brass, about an inch wide, a small portion of the end of which is turned down at right angles, and thinned with a hammer; the thin edge is then drawn forcibly through the oblique furrows of the file, and serves as a rake to remove any particles of metal that lodge therein.

But the best and most rapid mode of cleaning the file, is to nail to a piece of wood about two inches wide, a strip of the so-called *cotton card*, which constitutes a most effective brush, and answers the purpose exceedingly well. Some workmen, to lessen the disposition of the file to hold the file dust, or become pinny, rub it over with chalk; this absorbs any oil or grease that may be on the file, and in a considerable degree fulfils the end desired.

To remove wood-dust from files, floats, and rasps, some persons dip them for a few moments into hot water, and then brush them with a stiff brush. This plan, although effective, is neither general nor important.

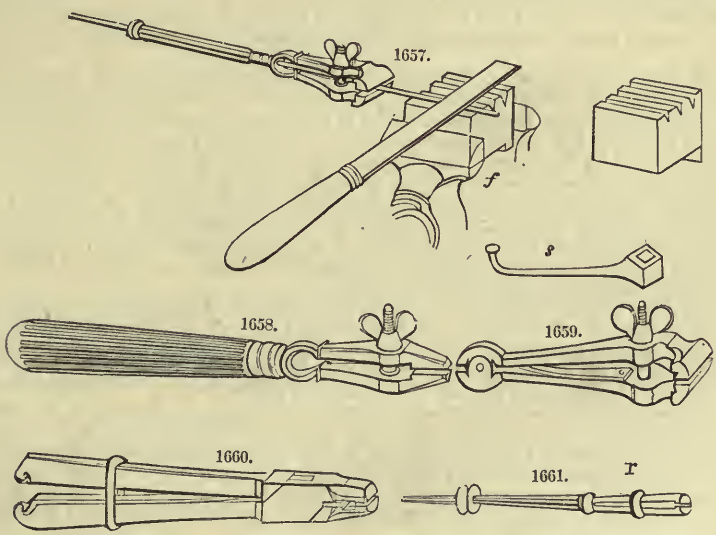
The principal methods of fixing works, in order to subject them to the action of the file, will be noticed under the heads, *Vice*, *Tail-vice*, and *Vice-bench*. However, many of the massive parts of machinery are so heavy, that gravity alone is sufficient to keep them steady under the action of the file, and for such as these, it is therefore only needed to prop them up in any convenient manner.

A great number of small works are more conveniently filed, whilst they are held with the left hand, the file being then managed exclusively with the right; this enables the artisan more easily to judge of the position of the file. In such cases, a piece of wood *f*, Fig. 1657, called a *filing-block*, is fixed in the table or tail-vice.

Pieces that are sufficiently long and bulky, are held upon the filing-block by the hand unassistedly; but small and short works are more usually fixed in some description of hand-vice, and applied in the position shown in Fig. 1657, and the vice being larger than the work, serves as a handle, and affords a better grasp.

For works of larger size the hand-vices are progressively larger, as in Figs. 1658 and 1659; some of them have wooden handles. Almost all the hand-vices have fly nuts to be twisted with the fingers, but the most powerful, which sometimes weigh as much as about three pounds, have square nuts that are fastened by a key or spanner *s*.

Hand-vices are not, however, in all cases employed; but small wires and other pieces are also held in a species of pliers, Fig. 1660, called *pin-tongs*, or *sliding-tongs*, which are closed by a ferule that is drawn down the stem. Fig. 1661 shows another variety of this kind, that has no joint, but springs open by elasticity alone when the ring *r* is drawn back.



1657. 1658. 1659. 1660. 1661.

The small pin-vice, Fig. 1657, is used by watchmakers in filing up small pins and other cylindrical objects; the jaws are not united by a joint, but are formed in one piece with the stem of the vice, the end that constitutes the jaws being divided or forked; the screw and stem are each perforated throughout, that the ends of long wires may be filed; and the stem is octangular that the pin-vice may be readily twisted to and fro. This is more usual in the narrow vices, Fig. 1658, known as *dog-nose* or *pig-nose* hand-vices, than in those with wide or *cross chaps*, Figs. 1657 and 1659.

Many circular works that were formerly thus filed, are now, from motives of expedition and accuracy, more commonly executed in the turning-lathe, since the great extension in the use of this machine, which has become nearly as general as the vice or the file itself; but frequent occasions still remain in which the hand-vice and file are thus employed.

In the pin-tongs, Fig. 1661, besides the facility of turning the instrument round with the fingers, from the reverse end having a centre and pulley, the same spring tongs serve conveniently as forceps for holding small drills to be worked with the drill-bow, and also for other purposes in watch-work.

Numerous flat works are too large, thin, and irregular in their superficies to admit of being fixed in the various kinds of bench-vices, as there would be risk of bending such thin pieces by the pressure of the vice applied against the edges of the work.

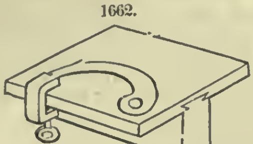
The largest flat works are simply laid on the naked surface of the work-bench, and temporarily

held by half a dozen or more pins or nails driven into the bench. The pins should be as close to the margin as possible, and yet below the surface of the work.

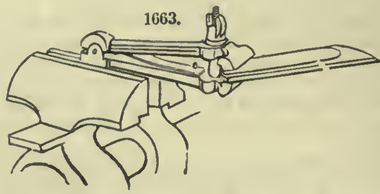
For thin flat works of smaller size, the filing-board, Fig. 1662, is a convenient appendage; it measures six or eight inches square, and has a stout rib on the under side, by which it is fixed in the vice.

In filing thin flat works, such as the thin handles or scales of penknives and razors, and the thin steel plates used in pocket-knives, cutlers generally resort to the contrivance represented in Fig. 1663 and known as a *flatting-vice*.

1662.



1663.



One face of the small filing-block *f*, Fig. 1657, is also used for very small thin works, and which are prevented slipping from the file by the wooden ledge, or by pins driven in. In many instances, also, thin works are held upon a piece of cork, beneath which is glued a square piece of wood, that the cork may be held in the vice without being compressed. The elasticity of the cork allows the work to become somewhat imbedded by the pressure of the file, between which and the surface-friction it is sufficiently secured for the purpose without pins.

Before any effective progress can be made in filing flat works, the operator must be provided with the means of testing the progressive advance of the work; he should therefore possess a *true straight-edge* and a true surface-plate. The straight-edges used by smiths are generally of steel, and although they have sometimes a nearly acute edge, it is much more usual to give them moderate width; thus, in steel straight-edges from one to four feet in length, the width of the edge is from one-sixteenth to one-fourth of an inch, and in cast-iron straight-edges from six to nine feet in length, the width is usually two to three inches.

The straight-edge is used for trying the surface that is under correction, along its four margins, across its two diagonals, and at various intermediate parts, which respective lines, if all exact, denote the surface to be correct; but the straight-edge alone is a tedious and scarcely sufficient test, and when great accuracy is desired, it is almost imperative to have at least one very exact plane metallic surface or surface plate, by which the general condition of the surface under formation may be more quickly and accurately tested at one operation; and to avoid confusion of terms, it is proposed in all cases, when speaking of the instrument, to employ the appellation planometer, which is exact and distinctive.

The flat piece of cast-iron intended to be operated upon, having been chipped all over, a coarse hand-file, of as large dimensions as the operator can safely manage, is selected, and in the commencement the rough edges or ridges left by the chipping chisel are levelled, those parts however being principally filed, that appear from the straight-edge to be too high.

The strokes of the file are directed sometimes square across as on a fixed line, or obliquely in both directions alternately; at other times the file is traversed a little to the right or left during the stroke, so as to make it apply to a portion of the work exceeding the width of the file. These changes in the applications of the file are almost constantly given, in order that the various positions may cross each other in all possible directions, and prevent the formation of partial hollows. The work is tried at short intervals with the straight-edge; and the eye directed on a level with the work to be tested, readily perceives the points that are most prominent. After the rough errors have been partially removed, the work is taken from the vice and struck edgeways upon the bench to shake off any loose filings, and it is then inverted on the planometer, which should be fully as large or larger than the work. As, however, it cannot be told by the eye which points of the work touch the planometer, this instrument is coated all over with some coloring matter, such as pulverized red chalk mixed with a little oil, and then the touching places become colored.

The work is slightly rubbed on the surface plate, and then picks up at its highest points some of the red matter; it is refixed in the vice, and the file is principally used in the vicinity of the colored parts, with the occasional test of the straight-edge, and after a short period the work is again tried on the planometer.

This process is continually repeated, and if watchfully performed it will be found that the points of contact will become gradually increased.

The grooved or roughing-out cutter is employed in the commencement, because it more rapidly penetrates the work, and a few strokes are given to crop off the highest points of the surface; the furrows made by the serrated cutter are then nearly removed with the file, which acts more expeditiously although less exactly than the plane, and in this manner the grooved plane iron and the coarse file are alternately used. In the absence of the planometer, the metal plane assumes a greatly increased degree of importance.

As the work becomes gradually nearer to truth, the grooved cutter is exchanged for that with a continuous or smooth edge; a second-cut, or bastard file, hand is also selected, and the same alternation of planing and filing is persevered in, the plane serving as it were to direct the file, until it is found that the plane iron acts too vigorously, as it is scarcely satisfied with merely scraping over the surface of the cast-iron; but when it acts it removes a shaving having a nearly measurable thickness, and therefore,

although the hand-plane may not injure the general truth of the surface, it will prevent the work from being so delicately acted upon, as the continuance of the process now demands; a smoother hand file is consequently alone employed in furthering the work.

If the piece of cast-iron should have been turned in the lathe, or planed in the planing machine, instead of having been wrought entirely with the chipping chisel, plane, and file, the former instructions would be uncalled for, as the remaining steps alone would remain to be followed.

It is now often usual to discontinue the use of the file, and to prosecute the work with a scraper, which having a sharp *edge*, instead of a broad and abrading *surface*, may be made to act with far more decision, on any, even the most minute spot or point. A worn-out triangular file, ground at the end on all the faces, so as to make thin keen edges, is generally used as the scraper; this should be keenly sharpened on an oil-stone, so as to act without requiring much pressure, which would only fill the work with striæ or utters.

In producing metallic surfaces the constant effort should be to reduce all the high places with as much expedition as circumstances will admit, but avoiding, on the other hand, that energetic use of the tool, which may too hastily alter the condition of the surface, and in expunging the known errors, induce others equal in degree but differently situated. Throughout the work, attempt should be made to keep the points of bearing, whether few or many, as nearly equidistant as may be, instead of allowing them to become grouped together in large patches.

The periods of alternation between the hand-plane and the file, and also the times when these are successively rejected, in favor of the scraper as the finishing tool, must be in great measure left to the judgment of the operator.

There should be a frequent examination of the work by means of the straight-edge and planometer, which latter should at all times be *evenly* tinted with the color.

It is not to be supposed that it is in every case needful to proceed in the careful and progressive mode just described, as the parts of different works require widely different degrees of perfection as to flatness. For instance, in many it is only necessary they should be clean and bright, and have the semblance of flatness; with such, even the straight-edge is little if at all used as a test. Those surfaces by which the stationary parts of framings are attached, require a moderate degree of accuracy, such as may be comparable with the perfection in the hewn stones of a bridge, which require to be flat, in order that they may bear fairly against each other, as without a certain degree of truth, the stone might break from the unequal strain to which it would be exposed.

The flat parts of metallic works, if similarly imperfect, would bend, and perhaps distort the remainder; but although it is of great importance that bearing surfaces should be out of winding, or not twisted, it is by no means important that such bearing surfaces should be continuous, as a few equally scattered bearing points frequently suffice. Thus it was the common practice before the general introduction of the planing machine, to make fillets around the margin of the bearing surfaces of castings, which fillets alone were corrected with the chisel and coarse file, for the juxtaposition of the larger pieces or framework of machines, the intermediate spaces being left depressed and out of contact. This mode sufficed, provided the pressure of the screw-bolts could not, by collapsing the hollow places, distort the castings, with which view chipping places were also generally left around the bolt-holes of the work: this method greatly reduced the labor of *getting up* such works by hand; but fillets and chipping places are now in a great measure abandoned. Smaller and more delicate works, requiring somewhat greater accuracy than those just described, are left from smoother files, but in most cases without the necessity of scraping; but the rectilinear slides and moving parts of accurate machinery, and the trial or surface-plates of the mechanician, require beyond all other works the most dexterous use of the file.

Until very recently, when the points of bearing had been so multiplied by the file and scraper, as not to exceed about half an inch in average distance, and that a still higher degree of accuracy was desired; it was the ordinary practice to attempt the obliteration of these minute errors by the method of grinding.

That two surfaces which are *very nearly accurate*, if ground together for a *very short time*, do in some degree correct each other, is true, but it has been long and well known, that a continuance of the grinding is very dangerous, and apt to lead the one surface to become convex, and the other concave in a nearly equal degree, and on this account three pieces were usually operated upon that the third might act as an umpire, as although two pieces possessing exactly opposite errors may appear quite to agree, the third cannot agree with each of these two until they have all been made alike, and quite plane surfaces.

But the entire process of grinding, although apparently good, is so fraught with uncertainty, that accurate mechanicians have long agreed that the *less grinding* that is employed on rectilinear works the better.

A further and equally important advantage results from the discontinuance of grinding, as regards the slides and moving parts of machinery. Some of the grinding powder is always absorbed in the pores of the metal, by which the metallic surfaces are converted into species of laps, so that the slides and works carry with them the sources of their depreciation and even destruction.

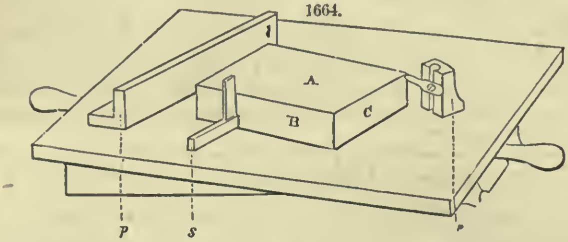
The former instructions have been restricted to the supposition that only one of the superficies of the work was required to be made plane or flat; but it frequently happens in rectangular works, such as the piece A B C, Fig. 1664, that all six surfaces, namely, the top and bottom A *a*, the two sides B *b*, and the two ends C *c*, all require to be corrected and made in rectangular arrangement, (the surfaces *a b c* being necessarily concealed from view,) and therefore some particulars of the ordinary method of producing these six surfaces will be added.

The general rule is first to file up the two largest and principal faces A and *a*, and afterwards the smaller faces or edges B *b*, and C *c*. The principal faces A *a*, especially when the pieces are thin, must be proceeded with for a period simultaneously, because of the liability of all materials to spring and alter in their form with the progressive removal of their substance, and on this account the work

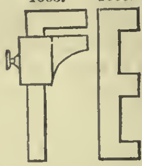
whether thick or thin, is frequently prepared to a certain stage at *every* part, before the final correction is attempted of any *one* part.

The straight-edge and surface-plate are required to prove that each of the faces A and *a* is a plane surface, and the callipers or a similar gage is also needful, to prove them to be in parallelism. Callipers, unless provided with set screws, are very liable to be accidentally shifted, and it is needful to use them with caution, otherwise their elasticity, arising from the length of their legs, is apt to deceive. There are gages, such as Fig. 1665, with short parallel jaws that open as on a slide, and are fixed by a side screw; and a still more simple and very safe plan is to file two rectangular notches, in a piece of sheet-iron or steel, as in Fig. 1666, the one notch exactly of the finished thickness the work is required to possess, the other a little larger to serve as the coarse or preliminary gage.

1664.



1665. 1666.



Sometimes the one face of the work, or A, having been filed moderately flat, a line is scored around the four sides of the work with a metal marking-gage, the same in principle as the marking-gage of the joiner. At other times the corrected face A is laid on a planometer larger than the work, and the marginal line is scribed on the four edges by a scribing point *p*, Fig. 1664, projecting from the sides of a little metal pedestal that bears truly on the surface-plate.

Chamfers or bevelled edges are then filed around the four edges of the face *a*, exactly to terminate on the scribed lines: the central part of *a* can be reduced with but little watchfulness, until the marginal chamfers are nearly obliterated. This saves much of the time that would be otherwise required for investigating the progress made; but towards the last, the callipers and planometer must be carefully and continually used, to assist in rendering A and *a* at the same time parallel and plane surfaces.

The two principal edges B *b* are then filed under the guidance of a square; the one arm of the square is applied on A or *a* at pleasure, as in joinery work; or if the square have a thick back it may be placed on the planometer, as at *s*, Fig. 1664; if preferred, the work may be supported on its edge B upon the planometer, and the back square also applied, as at *s*, in which case the entire length of the blade of the square comes into operation, and the irregularities of the plane B are at the same time rendered obvious by the planometer.

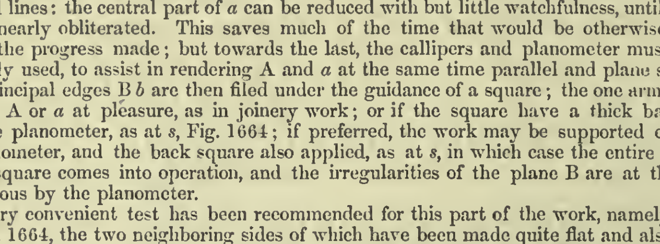
Another very convenient test has been recommended for this part of the work, namely, a stout bar, such as *r*, Fig. 1664, the two neighboring sides of which have been made quite flat and also square with each other. When the work and trial-bar are both laid down, the one side of the bar presents a truly perpendicular face, which may, by the intervention of coloring matter, be made to record on the work itself, the points in which B differs from a rectangular and vertical plane.

When the edge B has been rendered plane and square, the opposite edge *b* may in its turn be marked either with the gage or scribing-point at pleasure; the four edges of *b* may be then chamfered, and the entire surface of *b* is afterwards corrected, (as in producing the second face *a*,) under the guidance of the square, callipers, rectangular bar, and surface-plate, or some of these tests.

The ends C *c* now claim attention, and the marginal line is scribed around these by the aid of the back square alone; but the general method so closely resembles that just described as not to call for additional particulars.

Should one edge of the work be inclined, or bevelled, as in the three following figures, in which the works are shaded, to distinguish them from the tools, the rectangular parts are always first wrought,

1667. 1668. 1669. 1670.



1671. 1672. 1673. 1674.

and then the bevelled edges, the angles being denoted by a bevel instead of a square; either with a bevel having a movable blade, Fig. 1667, or by a bevelled templet made of sheet metal, as in Figs. 1668 or 1669, which latter cannot get misadjusted. The bevelled edge of the work is also applied if possible on the planometer; in fact, the planometer and bevel are conjointly used as the tests. Bevelled works

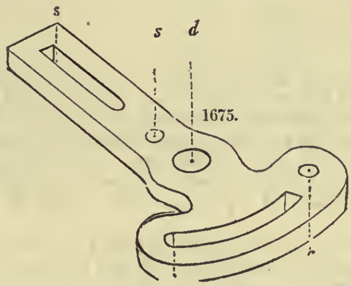
are either held in the vice by aid of the chamfer-clamps, or they are laid in wooden troughs, with grooves so inclined, that the edge to be filed is placed horizontally. Triangular bars of equilateral section are thus filed in troughs, the sides of which meet at an angle of 60 degrees, as in Fig. 1670.

The succeeding examples of works with many plane surfaces are objects with rebates and grooves, as represented in Figs. 1671 to 1674. Pieces of the sections, Figs. 1671 and 1672, supposing them to be short, would in general be formed in the solid, either from forgings or castings, as the case might be; the four exterior and more accessible faces would be filed up square and true, and afterwards the interior faces, with a due regard to their parallelism with the neighboring parts, just after the mode already set forth. The safe-edge of the file is now indispensable; as in filing the face *b* the safe-edge of the file is allowed to rub against the face *a* of the work, and which therefore serves for its guidance; and in filing the face *a* the side *b* becomes the guide for the file. The groove in Fig. 1672 requires a safe-edge square file.

When, however, pieces of these sections, but of greater lengths, have to be produced by means of the file alone, it is more usual to make them in two or three pieces respectively, as shown detached in Figs. 1673 and 1674; and which pieces are first rendered parallel on their several edges, and are then united by screws and steady pins.

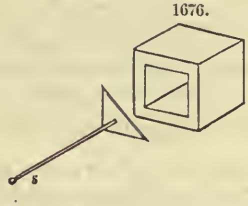
In works of these kinds, which have rebates, grooves, internal angles, or cavities, the square, with a sliding blade, shown in Fig. 1672, is very useful, as the blade serves as a gage for depth, besides acting as a square, the one arm of which may be made of the precise measure of the edge to be tried. This instrument is often called a turning square, as it is particularly useful for measuring the depth of boxes and other hollowed works turned in the lathe.

In making straight mortises, as at *s s*, Fig. 1675, unless the groove is roughly formed, at the forge, or in the foundry, it is usual to drill holes nearly as large as the width of the mortise, and in a straight line; the holes are then thrown into one another by a round file, or a cross-cutting chisel, and the sides of the mortise are afterwards filed square and true.



1675.

1676.



For a circular mortise *c c* the mode is just the same, with the exception that the holes are made on a circular line; and that, instead of a flat file being used throughout, a half-round or a crossing file is used for the concave side of the mortise.

Short rectangular mortises, or those which may be rather considered to be square holes, as in Fig. 1676, would, if large, be prepared by forging or casting the material into the form; and then the six exterior faces having been corrected, the aperture would be filed on all sides under guidance of some of the various tests before referred to. And in such a case it is convenient to employ a small square *s*, in the form of a right-angled triangle, to which is attached a wire that may serve as a handle, whereby the square may be applied at any part within the mortise without the sight of the workman being intercepted by his own fingers. Sometimes also a cubical block filed truly on four of its faces to the exact dimensions of the aperture, is used as a measure of the parallelism and flatness of the four interior faces.

The method first to be described is one that is considerably used in thick pieces of metal, for making holes differing from the circular form, such as square, hexagonal, triangular, elliptical, and other holes, by first drilling a round hole, and then enlarging and changing the section of the circular hole by a taper punch, better known as a *drift*, which tool is made of steel, and exactly of the same section as that required in the hole; the drift is hardened and tempered before use.

The drift for a taper square hole is made as in Fig. 1677, or simply as a square pyramid, considerably longer than the hole required; a round hole is first drilled in the work, just large enough to admit the small end of the drift, which is then driven in; its angles indent and force out the metal, making it first like the magnified line *m*, and ultimately exactly square, unless by mistake the hole were drilled too large, when the circular parts would not be quite obliterated. If admissible, the endlong blows on the drift are mingled with a few blows on the sides of the work, as at *b b*, or parallel with the sides of the drift, which cause the metal to adapt itself more readily to the tool. The drift must not, however, be used too violently, for as it acts as a wedge, it may burst open the work, and which latter is therefore mostly left strong and rough before being drifted; and generally, when the angles have been somewhat indented, they are partly filed out, and completed by the alternate employment of the file and drift, the marks made by the latter serving continually to indicate the parts to be removed with the file.

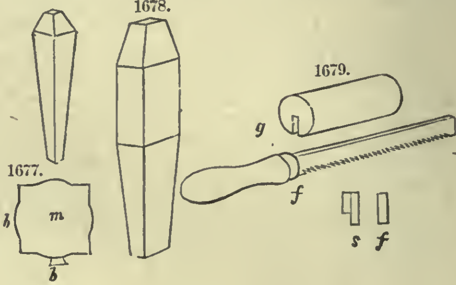
Taper square holes, such as those in the chucks for drills, are made with some facility. The chuck is first drilled on its own mandrel, and the drift is put in the four different ways in succession, that the errors incidental to its form may be scattered and lost; the chuck is also placed on the mandrel at intervals, with the drift in its place, that the drift may show, as it revolves, whether or not the hole is concentric. When it is required that the drifted hole should be parallel instead of taper, the drift is

made as in Fig. 1678; that is, parallel for a short portion in the middle of its length, and the extremities alone are tapered so as to make the tool smaller at each end; the work is therefore first gradually enlarged to admit the largest part of the drift, and the parallel part is then driven through the work, and renders the inner surface of the same a true counterpart of the drift, if proper care have been taken. In some few cases the sides of the drifts are notched with a file, so as to act as teeth; but this is not general.

When drifts are used, the interior surfaces are often completed before the exterior. The holes are first drifted whilst the work is larger than its intended size, and afterwards the exterior part is filed or turned, as the case may be, *from the hole*, that is, the hole is made the basis of the measurement of the exterior portions of the work.

In making by hand the key-ways in the round holes of the wheels, it is to be observed, that it is common to turn a cylindrical plug exactly to fill the hole, and to make a notch in the plug as wide as the intended key-way and parallel with the axis; the plug is shown at *g*, Fig. 1679. A piece of steel *f* is then filed parallel, and exactly to fit the notch, and its edge is cut as a file, and used as such within the guide-block, the latter being at the time inserted in the hole of the wheel. In this case the block becomes the director of the file, and the notches in any number of wheels are made both parallel and axial, and the only precaution that remains to be observed is in the depth of the notches, and this is not always important; the depth may however be readily determined by making the grooves at first a little shallower than their intended depth, and then, the plug having been removed from the hole, a stop is attached to the side of the file, parallel with its edge, as at *s*, to prevent its penetrating beyond the assigned depth.

1678. 1679. 1677.

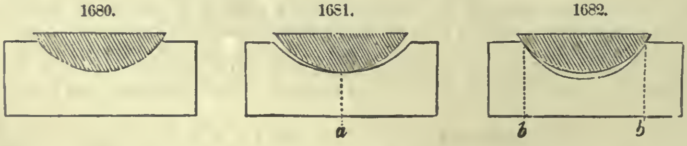


In filing works that are *convex*, flat files are always used, and the file is necessarily applied as a tangent to the curve; and in filing *concave* works round and half-round files are used, and in some cases they are selected, nearly or exactly as counterparts of the hollows to be wrought.

The manipulation of the file upon curvilinear works is entirely different from that required to produce a plane surface, in which latter case the work is held at rest and the hands are moved as steadily as possible in right lines; but in filing curved works an incessant change of direction is important, and so far as practicable, either the file, or the work, is made to rotate about the axis of the curve to be produced.

A semicircular groove of half an inch radius, as in Fig. 1680, would be most easily filed with a round file of nearly the same curvature, and the correspondence between the file and work, and consequently of their axes likewise, would render the matter very easy; but the file, from the irregularity of its teeth, would leave ridges in the work, unless in every stroke it were also twisted to and fro axially by the motion of the wrist, and occasionally in the reverse direction, so that the furrows made by the teeth might cross each other. If the groove to be filed had a diameter of three or four inches, although the file might be selected to correspond in curvature with the groove, as it would not embrace the entire hollow, the twisting and traversing of the file would be imperative in order to arrive at all parts of the work.

1680. 1681. 1682.



Under ordinary circumstances it is certainly best that the curvature of the file and work should agree as nearly as possible: but it is obvious that the file, if more convex than the work, can only touch the latter at one part, as at *a*, Fig. 1681; whereas, if the file is less convex, or flatter, than the work, it will act at two places, as at *b b*, Fig. 1682. Cutlers, in filing out the bows of scissors, always avail themselves of this circumstance, and until nearly the conclusion, use files flatter or less convex than the work.

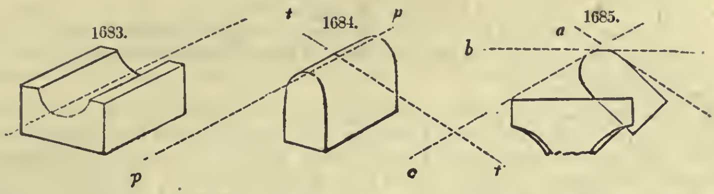
In filing concave works, there is but little choice of position, as the file is always parallel with the axis of the curve, as in the dotted line in Fig. 1683; but in convex works, such as Fig. 1684, the file may be applied either parallel with the axis as at *p p*, or transversely thereto as at *t t*. In general, however, the work would be fixed obliquely as in Fig. 1685, and the file would be first used transversely for some one or two strokes, at an inclination of about 30 degrees with the horizontal line, as at *a*, so as nearly to agree with the straight side of the object; the file would be successively raised to the horizontal, and depressed in the same degree on the other side; in fact, proceeding through the positions *a b c*, Fig. 1685, at some eight or ten intervals, and which would tend to make as many insignificant ridges upon the work. The ridges would be then melted together by swinging the hands from the position *a* to *c* in every stroke, to be repeated a few times; but as the entire semicircle could not be embraced at one stroke, the work would be re-fixed in two or more positions, so as to divide the operation into about three stages.

A more exact although less energetic method would be to place the file parallel with the axis, as on *p p*, Fig. 1684, and to sweep round the curve principally by the twisting motion of the wrist. A third

mode, frequently adopted in such small pieces as can be held upon the filing-block with the hand-vice, is to swing the work upon its axis, and to use the file with the right hand, as if on a flat surface.

Some works are curvilinear in both directions, such as curved arms and levers with rounded edges; many of these kinds are completed by draw-filing them, or rubbing the file sideways or laterally around the curve, instead of longitudinally as usual. The great majority of curved works are moulded and formed *prior* to the application of the file, which is then principally used to smooth and brighten them—other works are shaped almost entirely with the file, assisted by outlines drawn on the pieces themselves—and again other works are shaped with the file, under the guidance of templets or pattern-plates of hardened steel. Some observations will be offered on all three of these modes.

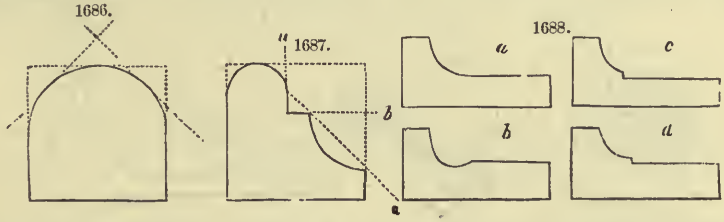
1683. 1684. 1685.



Firstly, in respect to filing up metal works that have been accurately shaped by founding or forging, little or nothing remains to be added, as the only object is to act on every part of curvilinear surfaces in the most expeditious and commodious manner, with the general aim of reducing any trifling errors of form that may already exist in them, and avoiding the introduction of new ones; which circumstances call for the frequent scrutiny of the eye, and an incessant yet judicious variation in the position of the hands.

Secondly, curved works that are moulded or formed almost entirely with the file. These are blocked out square, and the outlines of the curves are drawn on the ends and sides of the pieces, to guide the file in a manner analogous to the routine pursued by carpenters, masons, and other artisans. For instance, to form a bead, as in Fig. 1686, the work is prepared of a nearly rectangular form, and the half circle having been drawn at each end, the angles of the works are coarsely removed at about 45 degrees, making the end a semi-octagon; sometimes the four angles are farther reduced, giving to the work eight facets, prior to their being thrown together in making the general curve. If these sides are made with only a very moderate degree of exactness, they will greatly tend to preserve the uniformity of section throughout.

1686. 1687. 1688.



Many workmen, when they have removed the two principal angles at 45 degrees, make a chamfer entirely around the semicircle at each end, to guide the file in hastily reducing the principal bulk of the material. It is also desirable that the straight-edge should be frequently applied along the axis of the curve, at various parts, during the progress of the work.

Should the entire piece, Fig. 1687, have to be made from a solid block, two cuts *a* and *b*, made with the saw, would remove the corner. The round part of the bead would be made as before, and previous to filing the hollow, it would be chamfered on the line *c*; a half-round file, of less curvature than the hollow itself, would be first sunk in the middle of the chamfer, and the hollow would be deepened and extended sideways, always maintaining an easy curve, until it reached the marginal lines where the hollow meets the plane surfaces.

Where hollows run on to right lines as at *a*, Fig. 1688, there is some risk of making a break in the junction, either from the curve sinking below the right line, as at *b*, or from the straight line, as at *c*, advancing too far and breaking in upon the curve. On this account a break or fillet is usually made at the part as at *d*, or else it is usual primarily to give that form, by filing the flat first, and then sinking down the hollow just to meet it, and at the conclusion letting the half-round file run a little way on to the right line. Some, however, prefer the opposite course, or that of sinking the hollow to its full depth, and then filing down the remainder with the flat file, but which mode is certainly attended with more risk.

Thirdly, curved works that are shaped with the file under the guidance of templets or pattern-plates of hardened steel. This mode is much followed in works of two principal kinds, namely, thin works required in great numbers and precisely of one form, and in a variety of works that require to be exactly circular, although they may not admit of being so fashioned in the lathe.

Many thin works of the first kind are stamped or punched out of the sheet metals, as for instance, the washers for machinery, the links of jointed chains, steel pens, parts of locks for joinery, and numerous other thin works; but many objects of larger kinds, and that are not wanted in such large numbers, are not stamped, but are either cast, or cut out with the shears, and afterwards filed between templets.

The snail-wheel of a striking clock, Fig. 1689, is frequently thus formed, by means of a templet: it

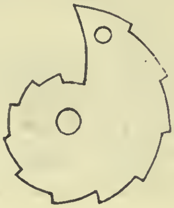
has an edge formed in twelve steps, arranged spirally, the positions of which determine the number of strokes of the hammer on the bell. In this case, which will serve as a general example, a piece of sheet-steel is cut out, flattened, and smoothed on one side, to receive the drawing of the snail-wheel, and a second piece is also prepared. The two are first drilled together with a central hole, and another hole as distant from the centre as admissible. The two plates are then united by two pins, and the outline of the work having been drawn on one of them, they are next filed in steps carefully to the lines, and square across the edges, and they are afterwards hardened and slightly tempered to lessen their liability to fracture on being pinched in the vice. The dozen or more snail-wheels having been cast, or cut out of sheet-brass, and flattened with the hammer, two or three at a time are pinched alongside one of the templets, whilst the two pin-holes are made with the breast-drill or in the lathe, with a drill that exactly fits the holes in the templets. It only remains to place the dozen plates between the templets, keeping them in position by two pins extending through the whole number, and then all the notches are filed in the brass plates, until the file *very nearly* touches the steel patterns, as absolute abrasion on the steel itself would greatly injure the files. In this mode the several brass plates become very exact copies of the pattern.

Templets are as much used for setting out and producing series of holes in any special arrangement, as in filing works to any particular form: a complex example of templets being used in this manner, is in drilling the side plates of harps intended for the arbors and link-works, used in temporarily shortening the strings. The respective positions of the holes in these side plates require a most exact arrangement, any departure from which, would prevent that precise shortening of the string required to produce the semitones with critical accuracy, and would also cause an unbearable jar, unless the cranks of the harp were severally in true position, or on the lines of centres, so as firmly to support the tension of the strings under all circumstances.

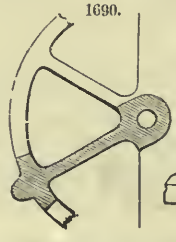
A different application of templets is sometimes met with in filing up numerous similar parts in the same object, as the arms or crosses for the wheels of clocks and other machines. The exact pattern of one spoke is filed up as a templet, which is shaded in Fig. 1690, and serves for the similar configuration of every spoke; the position of the templet being given by a central pin, aided by any little contrivance which catches into the 3, 4, 5, or 6, equidistant teeth corresponding with the number of arms.

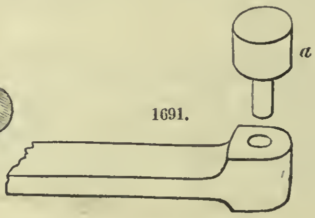
It frequently happens that certain forged, cast, and other works have parts, known as bosses, swells, collars, and knuckles, that are pierced with holes, which require their flat surfaces and also their margins to be made partially or entirely concentric with the holes. When such parts occur as bosses, they often project from a flat surface, and after the central hole is drilled, some of the pin-drills, or analogous tools used in drilling machines, are employed in finishing the margins.

1689.



1690.





1691.

When the circular margins are discontinuous, files and templets are more or less required: thus the extremity of a forged arm, such as Fig. 1691, is drilled, and in the configuration of the remaining parts, if but one or two such pieces are to be made, a boss or plug of wood is turned like *a*, that shall fit the hole; the shoulder of the wood is then rubbed with red chalk to mark that part of the surface which is not at right angles to the hole, and the circular edge of the boss serves for the guidance of the file in finishing the exterior margin; visually rather than obstructively, as the wooden boss would be reduced instead of the file being checked. If therefore many such objects had to be filed, two bosses or templets would be made of hardened steel, and used one at each extremity of the hole, and they would be held in position by grasping the three pieces collectively in the tail-vice. The same general method is very largely and more rigorously followed in making joints or hinges.

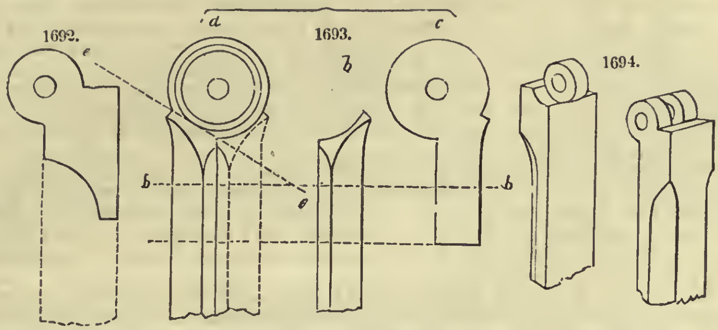
The brass and steel plates, Fig. 1692, used for the joints of carpenters' rules are filed up to templets in all respects after the manner described in reference to the snail-wheel, Fig. 1689, and the joint plates are inlaid by means of the file, saw, chisel, and plane.

The joints of drawing-compasses are made somewhat differently, and mostly as follows: The solid knuckle *a*, Fig. 1693, is first drilled and made circular by aid of a templet *c*, and the hollow side *b* is filed to correspond exactly with *a*; the two are then pinched together in the vice on the line *d d*, and the parallel notches for the steel joint-plates are made in each with the saw, as deep as the line *e e*. The parts *a* and *b* are then separated, the notches in *b* are completed with the frame-saw, and the bottom of the notches in *a* are rendered circular with the joint-saw. The middle plates, when filed a little larger than the templets *c*, are inserted in *b*, and soldered in their places; the two parts are smoothed on their various internal surfaces, and united by a temporary joint-pin, and any little irregularities in the external or circular curves, (which are left purposely a trifle too large,) are mutually detected by their want of agreement when the joint is opened to different distances; any parts in excess are very carefully reduced with a small smooth file, principally by draw-filing, after which the screw-pin with its brass cheeks or bosses is added.

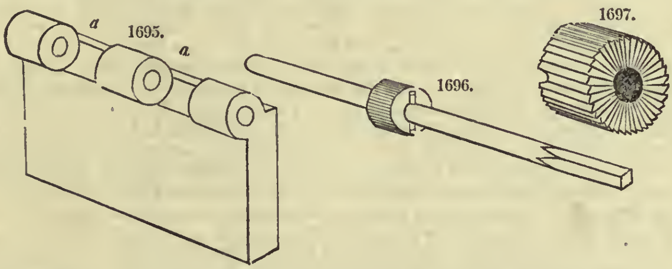
The pin-drill is commonly used for cutting out the concave parts that extend to the side of small

compass-joints, such as are represented in Fig. 1694, and also for inlaying the heads of small countersunk screws.

Larger joints with wider knuckles, such as Fig. 1695, are in many instances cast from patterns closely resembling the finished works. In such cases the first process is generally to remove any little external errors with the file, and to clear the angles with a small chipping chisel; the faces of the knuckles are then smoothed and inserted within one another very tightly. The joint-hole is afterwards drilled throughout all the knuckles, and which are filed up externally, sometimes under the guidance of templets put at the ends, but principally by the reduction of those high parts which get scratched or rubbed by the opposite parts, and thereby show their excess of height.



But if such joints are required to be made more accurately, the holes are first drilled in each piece separately, and rather too close in the corners; the holes are broached with a parallel broach, so as exactly to admit a steel cylinder, Fig. 1696, which has a square end for the brace; this rod is intended to receive the cutters, shown on a larger scale in Fig. 1697, which are cylindrical pieces of steel bored to fit the rod, and cut with teeth on the outer cylindrical part and on one flat surface; a pin is inserted through both the cutter and bar, so that the two may be united after they have been placed within the joint to be worked; sometimes the back face of the cutter has only a diametrical notch to receive the driving-pin, which pushes the cutter before it as it revolves. A recess must first be cleared for the cutter with a chisel and hammer, or by a wide-joint saw or cutter; and the hollowed parts at *a a*, Fig. 1695, are then cut throughout their length with the cutter, that afterwards serves to flatten the faces of the knuckles in exact parallelism throughout, and at right angles to the central hole.



The two halves of the joint, having been separately hollowed, and faced until the knuckles will penetrate some distance into one another, the external parts of the joint are next separately filed under the guidance of hard steel rings, or templets, of the same diameter as the cutter, and placed on the cylindrical rod; after which, the two parts of the joint are put together when yet slightly too large, and the central pin is inserted, in order that the rubbing of the knuckles against the corresponding hollows may denote the parts that are still too high or full; and by cautiously removing all the parts that are abraded, the joints may be made to fit very closely and accurately, and yet to move with great smoothness.

Many joints that are at the same time wide and small, as in hinged snuff-boxes, could not be drilled, as above described, with safety, and are therefore made quite differently, by means of small tube, called joint-wire.

For instance, in making a snuff-box, the rims for the top and bottom are fitted and jointed together before the top and bottom plates are soldered in, and the joint is thus constructed. Supposing that five knuckles are required for the bottom, and four for the top, the nine pieces of joint-wire are cut off, and filed square at the ends; the rims for the top and bottom having been fitted so as to form the rebate, are placed together, and carefully filed out with a semicircular recess, or groove, by means of a parallel round file, or a joint-file, exactly of the diameter of the joint-wire, which therefore leaves a hollow equal to the fourth part of the circle in each rim.

Five of the joint-pieces are then strung on a wire, inserted in the hollow of the rim for the bottom of the box, and tied therein with fine binding wire; the intervals between these five knuckles are regulated by inserting the other four between them for the moment, while the binding wire is being fastened; after which this first series of knuckles is soldered in with moderately hard silver solder, which

is usually fused with the blow-pipe. The lid is then treated in the same manner, and the bottom part of the box now serves as the gage for regulating the distance between the knuckles in the top rim. The same plan is also used by mathematical instrument makers and others, who however more generally turn the joint-pieces in the lathe, as the draw-bench forms no part of their ordinary supply of tools; and the wide joint-pieces or knuckles in mathematical works are usually larger than could be produced in that manner.

FILTRATION. The process of separating liquids from the substances mechanically suspended in them, by passing them through some porous material, sufficiently compact to retain the insoluble matters.

The materials employed as filters are numerous; as, porous stone, broken stone, glass or earthenware, gravel, sand, sawdust, pulverized charcoal, chaff, straw, sponge, paper, cotton and linen, and woollen cloth. These and many other things are made use of in the arts, but some of them have a particular application as being better suited to the character of the liquid to be strained, and the perfection required in the process. Thus, unsized or filtering paper is generally used for chemical purposes; charcoal for oils and sirups. Care should be taken in the selection of the material that no injurious chemical action ensue, so that the liquid, in passing through, may not lose any essential quality nor acquire any deleterious one.

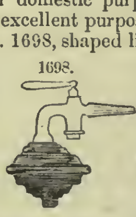
Under the heads, sugar, oil, &c., will be found a description of the filters used in their manufacture; we shall confine ourselves now to the filters used for the purification of water for the supply of cities and towns, and for domestic purposes. In all filters the rapidity with which the liquid passes through the filtering materials, or the quantity of strained liquid discharged in a given time, depends on the porosity of the filtering materials, the extent of their surface, the fluidity of the liquid itself, and the pressure under which it is forced through.

Among the first plans adopted for filtering on a large scale was by drawing the water into trenches, excavated below the level, beside, and a few feet distant from the stream which was to afford the supply; the intervening earth forming a natural filter. This arrangement has been found to answer well in some cases where the trenches excavated were extensive in comparison with the supply; but where from the demand, the level of the water in the trench is drawn considerably below that of the stream, so that the water passes through under pressure of some amount, the rapidity of the percolation of the water is found to diminish rapidly, from the drawing off of the finer earths into the body of the filter, filling up the interstices. New trenches have now to be excavated, in addition, and this is but a temporary relief, and, to prevent the filling up of the trenches, they have to be walled up and covered; on the whole, this plan of filtering was found to be expensive, especially when a large supply was needed.

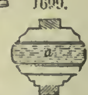
At the Chelsea Water Works, London, two subsiding reservoirs are used, so that the water in one of them can always be in repose, so as to deposit the heavier matters in suspension; a precaution always, if possible, to be adopted. After the deposition, the water passes through a filter of gravel and sand in a third reservoir. From time to time the top layer of sand is stirred up and renewed, and in course of time the whole material of the filter. This is of course expensive, and some readier and cheaper way of *cleansing* the filtering material has been sought. This has been effected by changing the direction of the current of water; that is, if the water has been passing down through the filter, to make it pass up, or vice versa: by this means the material is cleansed and continues to serve the purpose of filtering without replacing or change, and on this principle most filters are at present constructed.

No large filtering apparatus is attached to the Croton Water Works, but for domestic purposes the diaphragm filter of W. M. Gibson, of New York, has been found to answer an excellent purpose, and is in extensive use throughout the United States. It consists of a metal box, Fig. 1698, shaped like a dish or flattened spheroid, about five inches in diameter, and not larger than a pint measure, with a screw-fitted orifice in the centre, on both sides, either orifice of which is screwed to the hydrant pipe faucet, and is adapted to any vessel, pipe, or reservoir; the filter suffers the water to pass through, but retains the impurities. The quartz *a*, Fig. 1699, is enclosed between two diaphragms of fine silver wire gauze and Britannia metal plates, and the water passes through both the gauze and the crushed quartz. To clean the filter, unscrew and reverse it once a day, and the water will instantly wash away the sediment, slime, animalculæ, and all other impurities, and then run pure, clear, and pellucid as before. They can be attached to any hydrant, and under a pressure of eight feet head, will deliver a gallon a minute.

1698.



1699.



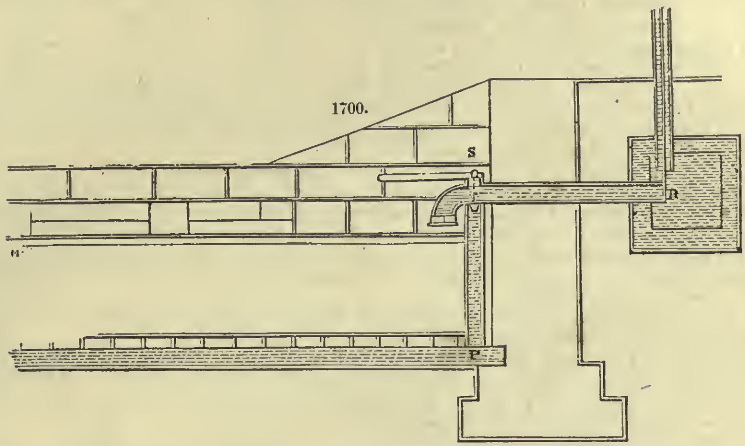
Large filters, on the same principle, are made for manufacturing purposes, which can render 200 to 400 barrels of turbid water clear in an hour.

The following is the construction of a filter on a more extensive scale: The stone pipe A brings the water from the regulating basin to the filters, and iron pipes communicate between the stone pipe or aqueduct and the top and bottom of the filters.

A valve near the top of the iron pipe S P, at S, Fig. 1700, forces the water to enter on the top or at the bottom of the filter at pleasure. The filter is 100 feet in length, and 60 feet in breadth, divided into three compartments, which may either act together or separately, so that when one compartment is being cleansed, the other two continue in operation. The site of the filters is a piece of level ground, excavated to the depth of 6 or 8 feet, with retaining walls all round, joined with cement, and puddled behind, so as to become water-tight. The bottom is laid about a foot deep with strong stiff puddle, over which is a pavement so cemented as to be impervious to water. The whole of this bottom is then divided into drains or spaces, 1 foot wide, and 5 inches deep, by means of fire-brick laid on edge, and covered with flat tiles, of the same material, perforated with small holes, like those used in a kiln for drying oats. These holes are placed very near each other, and are rather more than 1-10th of an inch in diameter; there is also a space of ¼ of an inch left open between the ends of the bricks, which support the perforated tiles, and their upper edges are little more than an inch broad, in order that there

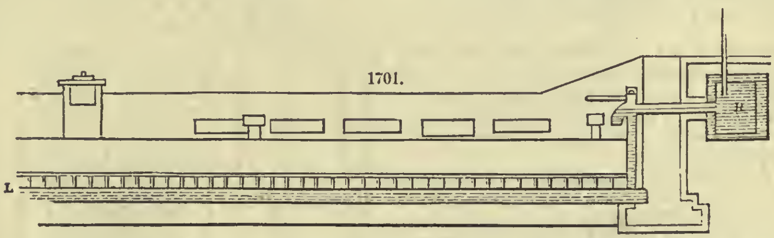
may be no space without holes, and nothing to prevent the water spreading equally over every part of the bottom of these drains. This is particularly necessary when the filters are being cleaned by the upward motion of the water. The perforated tiles or plates are covered to the depth of 1 inch with clean gravel, about 3-10th of an inch in diameter; this is followed by five other layers of gravel, each of the same depth, and each succeeding layer a little finer than the previous one, the last being coarse sand: over this is placed 2 feet depth of clean, sharp, fine sand, similar to that used in hour-glasses, but a very little coarser; about 6 or 8 inches deep of the fine sand nearest the top is mixed with ani-

1700.



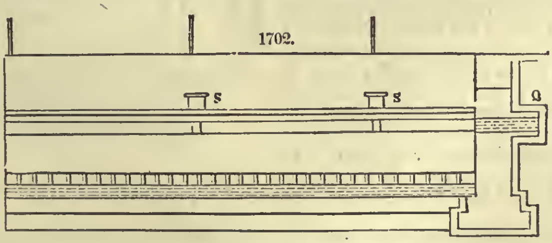
mal charcoal, ground to the size of coarse meal, each particle about 1-16th of an inch in diameter. A longitudinal drain or pipe N runs between the filter and the pure-water basin, communicating with both; on each of the openings between the pipe and the filter is a stop-cock to close the communication when necessary; there are also two drains, to carry off the foul water when the filters are being cleaned, and another to prevent the water from rising too high: when the filter is complete, its action is as follows: The sluice R and the valve S are opened, and the water permitted to flow through the filter into the drain N below, until it becomes quite clear. This will take two or three days when first set to

1701.



work, unless very great pains are taken to wash the gravel and sand before they are put into the filter, which will now flow copiously for some weeks, and when the quantity passing begins to decrease, the stop-cocks are shut, and the valve S S raised. The water then enters below, filling all the drains, and having a head pressure of several feet it will force its way up through the sand to the top, and in its passage raise the scales or particles of mud which have been deposited in the downward passage, and carry them into the foul-water drain below. If the sand of the surface be stirred by a fine-toothed rake

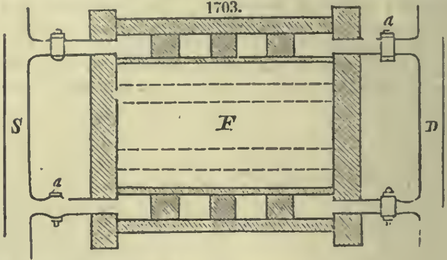
1702.



after the water has been raised above it, and a little additional water admitted on the top, through the conduit, it will facilitate the operation of cleaning, as the mud is always deposited on the very surface of the sand. By this means the sediment will be carried off, and the water pass through quite clear again in a few hours: the valves S should then be lowered, the stop-cocks opened, and the operation of filtering will again proceed as above described. The cost of this filter would be about $3000, and the quantity of pure water produced regularly every 24 hours on an average about 106,632 cubic feet.

M. Fonvielle, of Paris, has invented a filter in which two currents of water instead of one are employed to cleanse the materials used for filtering. This arrangement can be readily understood from the section, Fig. 1703, in which S is the pipe supplying water to the filter D, the discharge pipe; *a a*, stop-cocks by which the current may be made to pass in any direction through the filtering material F, which is supported between two perforated diaphragm plates. When in operation one cock only in each pipe is opened, diagonally opposite, as shown in the section. But to cleanse the filtering materials, both supply-cocks are opened and one discharge-cock, alternately the lower and upper; by this means the filtering materials are effectually cleansed. Filters on this principle, with numerous compartments and of various capacities, are used for the filtration of the waters of the Seine, and give complete satisfaction.

1703.

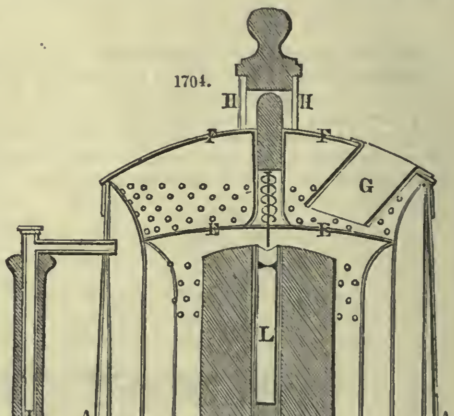


A floating filtering pump has been patented in England. A float supports the filter submerged a few inches, and it is connected by a pipe with a joint or piece of hose to the pump. By these means the water is drawn always from near the surface of the water, where the least matter is suspended. Without the filter a floating supply-pipe, whose apefture is always a few inches only below the surface of the water, would be a useful appendage to many pumps, since water drawn from near the bottom of a reservoir is very apt to be turbid.

FIRE ANNIHILATOR. A portable machine for domestic use, which is stated to possess the power of almost instantaneously extinguishing fire.

Fig. 1704 exhibits a section of the annihilator, which is composed of a set of light iron cases, thus arranged: A and B the two outer cases, forming a close water-chamber; C and D two inner cases, perforated in such a manner as to allow the free passage of vapor; E the inner lid; F the outer lid, or cover; G a water-pipe, forming the handle; H the charge; I the igniter; K the igniting-pin. The work of charging the machine is performed in a minute. The two lids F and E being taken off, the charge (which is already provided with the igniter bottle) is introduced, and the two lids are replaced, the outer one being secured by a thumb-screw. The igniter pin is placed in the neck, and covered with the wooden stopper, and this may be sealed down at pleasure. Water is then poured into the handle, and confined by a small screw-plug.

1704.



The charge K is a compound of charcoal, nitre, and gypsum, moulded into the form of a brick. The igniter I is a glass tube enclosing two bottles —one containing a few drops of sulphuric acid, placed over another containing a mixture of chlorate of potassa and sugar.

The mode of using the annihilator is to carry the machine to the place on fire, take out the wooden stopper, with the knob of the stopper strike down the plug or pin in the neck of the machine, and hold the machine by the handle in the best position for the vapor, which will come out of the hole on the top to reach the flame, which is almost momentarily extinguished. The action of the machine is as follows: The pin being forced down, breaks the igniter bottle, when the sulphuric acid falling on the mixture of chlorate of potassa and sugar, ignition takes place; the flame spreads over the upper surface of the charge, which instantaneously ignites, and evolves heated gases; these, in their passage through the perforated cylinders, impinge against the water-chamber, expand the contained air, and produce steam, by which the water is forced through the tubular passage. The steam of the water mixing in the annular chamber with the hot gases, they escape together from the discharge tube in a dense expansive cloud, and are continuously delivered until the charge and water are expended.

Mr. Phillips, the inventor, states the portable machine to be applicable to the protection of dwelling houses, detached buildings, and ships; but it is requisite that public stores, warehouses, manufactories, and large pile of building, be protected by stationary engines of immense power, the construction of which varies materially from that of the portable machine, although based on the same principle of action; namely, that of extinguishing fire by gases and vapor resulting from combustion

FIRE-ARMS. See Guns.

FIRE BOX. See Details of Engines, page 508.

Eng^{d} by W. G. Jackman.

James Reynolds

INVENTOR OF MACHINERY FOR INSULATING TELEGRAPH WIRE FOR SUBMARINE PURPOSES

N.Y. D. Appleton & C°

FIRE-BRICKS. Used for furnaces and the lining of stoves where great heat is generated, are moulded in various parts of the United States. At Newark, Amboy, and other places in New Jersey, where the loam contains a considerable amount of sand, they are made in large quantities. *Rondout* (on the river Hudson) and *Long Island* bricks are a similar quality, and will stand the action of great heat.

Retorts for a variety of purposes are made with a mixture of clay and iron, particularly for the manufacture of gas; the iron retort receiving a casing of prepared clay, which permits the fire to act first on the clay, and thus prevents the rapid destruction of the metal.

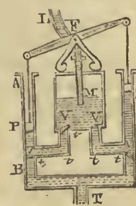
Retorts or bricks made of one part pure clay and three parts of coarse and pure sand, slowly dried and annealed, will resist a very high temperature, and are not readily fused; but if in contact with any metals in a fusible state, which are suffered to oxidize, they will then act upon the earthy matter, and cause it rapidly to fuse.

A long-continued white heat will soften the compound made of any of the silicious and aluminous earths; therefore clay and sand are not so well adapted to bear a great heat as an entire clay; coarsely powdered and burnt clay being substituted for sand, the vessels which contain glass in the furnace, and which are subjected to intense heats, are thus made, and resist for a length of time the action of the saline fluxes they contain.

Windsor loam, or a mixture of clay and sand, made by beating a thin paste, is employed as a lute to unite the joints of fire-bricks, or to set them in instead of common mortar; and if it is required that vitrefaction should take place with the clay so used, borax or red lead, mixed in small portions, will produce the effect; such a compound will destroy the porosity of earthenware, when exposed to high temperatures. See FLOATING BRICKS.

FIRE ENGINE. This most useful machine is constructed in a variety of forms, which all, however, agree in one principle. It generally consists of a double forcing pump communicating with the same air vessel; and instead of a force-pipe, a flexible leathern hose is used, through which the water is driven by the pressure of the condensed air in the air vessel. The annexed diagram represents a section of the apparatus. The pipe T descends into a receiver or vessel containing a supply of water. This pipe communicates with two suction valves V, which open into the pump barrels of two forcing pumps A B, in which solid pistons P are placed. The piston-rods of these are connected with a working beam F, elongated, so that a number of persons may work at both ends of it at once. Force-pipes *t t* proceed from the sides of the pump barrel above the valves V, and they communicate with an air vessel M, by means of forcing valves V, which also open upwards. The pipe descends into the air vessel near the bottom. This pipe is connected with the flexible leathern hose L, the length of which is adapted to the purposes to which the machine is to be applied. The extremity of the hose may be carried in any direction, and may be introduced through the doors and windows of buildings. By the alternate action of the pistons, water is drawn through the suction valve, and propelled through the forcing valves until the air in the top of the vessel M is highly compressed. The pressure acts on the surface of the water in the vessel, and forces it through the leathern hose in a continued stream, so as to spout from its extremity with a force depending partly on the degree of condensation, and partly on the elevation of the extremity of the hose above the level of the engine. It is to be considered that the pressure of the condensed air has, in the first instance, to support a column of water, the height of which is equal to the level of the end of the tube above the level of the water in the air vessel; and until the pressure exceeds what is necessary for this purpose, no water can spout from the end of the hose; and, consequently, the force with which it will so spout will be proportional to the excess of the pressure of the condensed air above the weight of the column of water, the height of which is equal to the elevation of the end of the hose above the level of the water in the air vessel.

1705.



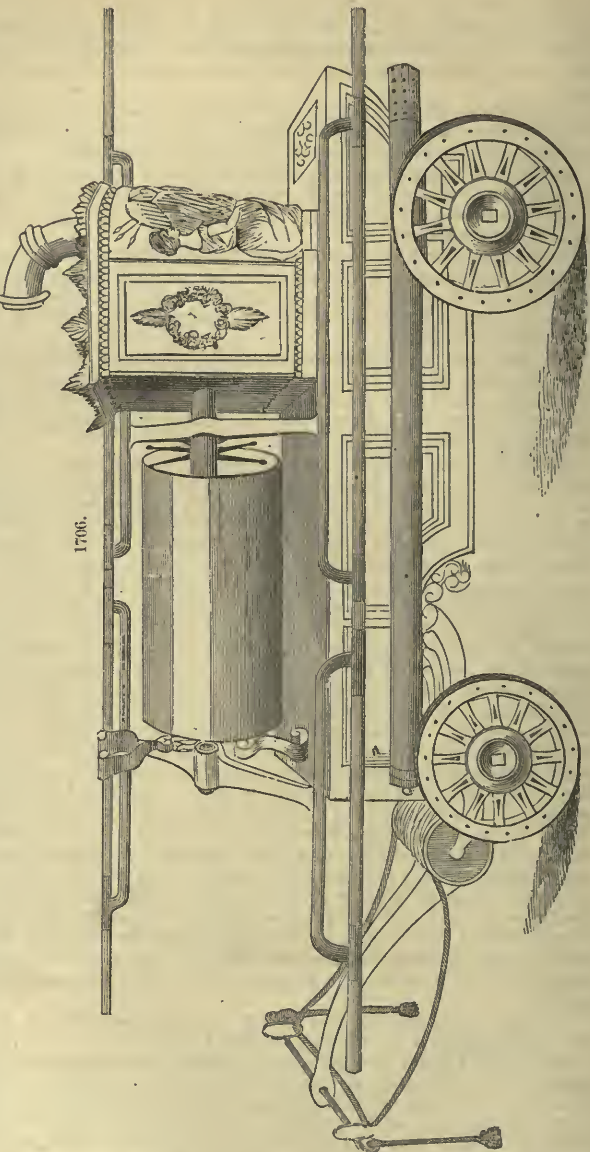
The fire engine has received various improvements from 1518 to the present time. The above description applies to our ordinary engines, Fig. 1706.

Braithwaite's *steam fire-engine* is an application of the power of steam to the working of the fire engine. The mechanical arrangement consists of two cylinders of about six inches in diameter, one of them being the steam cylinder, and the other the water pump; and they are placed horizontally, so that a parallel motion is easily produced. This engine will deliver 9000 gallons of water an hour at the height of 90 feet. The time of getting the machine into action, from the time of igniting the fuel, (the water being cold,) is only 18 minutes. Some of the fire insurance companies in London have floating engines on the Thames, which are extremely serviceable in cases of fire among the shipping or buildings near the river.

Steam fire engines have been for some years in successful use at Cincinnati. The great peculiarity of these engines is the boiler: the following is the description of the boiler of Shawk's engine. The sides of the fire are surrounded by a continuous series of pipes, arranged so as to form a square casing about it, which after being built up to a sufficient height, are then returned backward and forward over the fire, and piled in successive layers until a sufficient length is obtained; the pipes gradually increasing in calibre as the total length increases. The water is injected into the lower end of the coil, and takes up the heat from the pipes until it is converted into steam and is delivered into a strong cylinder, being compelled to pass through water contained therein. This steam chamber communicates, by means of a pipe from its upper end, with another and larger cylinder which forms part of the frame-work or foundation of the pumping apparatus. This boiler is capable of raising effective steam in ten minutes, being always kept ready; they are fired as they leave the house, and on their arrival at a fire, have a full head of steam ready for working. The use of these engines, according to a late report of the chiel engineer, has materially reduced the losses by fire, yet steam fire engines have not been incorporated into the fire service of other cities; in a few isolated instances they have been tried, but have not bee brought into practical use.

For a stationary steam fire engine none are more simple and effective than the Worthington Steam Pumps, (See PUMPING ENGINES.) They are in very general use on board of steam vessels; and on the ferry boats of this city, they make useful auxiliaries in cases of fire at the docks. A common and convenient form of fire engine is shown, Fig. 1706, taken from one of the smaller New York engines. The cylinder shown on top of the carriage contains a reel, on which is wound a supply of hose. It is usually protected by a cover of patent-leather, tastily ornamented. A suction-hose is swung on the side of the engine. Generally the hose is carried on a separate carriage, and when the supply of water is to be taken from an aqueduct the suction-hose is unnecessary. In this engine it will be perceived that the power is applied by brakes, and that the movement is up and down. To increase the power of such engines, in some places, a rope is attached to each of the brakes, which passing over blocks or sheaves fastened to the bottom of the carriage, are grasped by rows of men at right angles to the body of the engine, who, by reciprocating pulls, assist very much the men at the brakes.

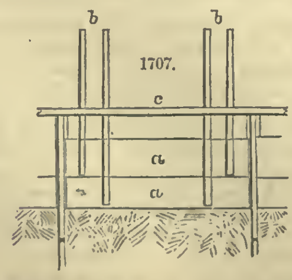
1706.

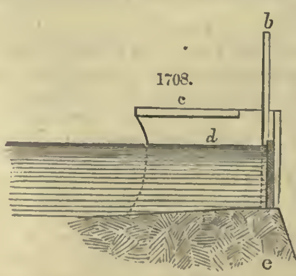


Besides the up and down brakes there are engines in much use in Cincinnati and at the West, in which the movement is horizontal; the men sit at their work, and the action is similar to that of rowing.

Various engines on the rotary principle have been constructed. The power was generally applied by means of a crank, but they were found very laborious in their operation, and liable to disarrangement. They are now seldom used as fire engines in the common acceptation of the term; but as stationary force-pumps, driven by steam or water, there are some which are extremely valuable and useful. See PUMP.

FLASH BOARDS. Movable boards placed on the top of a dam or weir, to retain the water of the





stream when the flow is small; which, in case of floods, are removed to give free vent to the surplus. In case of low water, therefore, they maintain the head, and in case of freshets, there is less obstructior

and less danger from flowage than if the structure was permanent to the level of the top of the flash boards. On the dams of the rivers which, when swollen, bring down ice or flood-wood, flash boards are used, of rough boards supported by iron rods inserted in the top of the dam, the joints being stopped with saw-dust, shavings, or gravel; and as the water rises the irons are bent down, and the boards are swept off by the flood. Where there is no danger from ice or floating lumber, or very sudden rising of the water, flash boards *a* are constructed so as to be removed by hand, Figs. 1708 and 1707, about 4 feet long, and from 6 inches to 12 inches wide, with long handles *b* at each end, at right angles to the board, by which a person standing on the platform *c* can raise the boards. They rest in the rabbits of posts or stanchions *d*, and are placed one above another to the required height. Flash boards of this form being easily managed, are almost invariably used on the waste-weirs of canals, to regulate the height or level of the water.

FLASHING. The accumulating of a flow of water, by movable constructions, for the purposes of manufacturing, navigation, or scouring.

FLASK. The iron or wooden frame or box which serves in foundries to support and contain the sand used in moulding. See CASTING, Figs. 807 to 836.

FLAX, *Machinery for preparing and spinning.* Flax, compared with the other materials used in the textile manufactures, such as wool and cotton, possesses several characteristic properties. While the latter are presented by nature in the form of insulated fibres, which simply require to be freed from their impurities previously to being spun, the former must have its filaments separated from each other by tedious and careful treatment. This circumstance has opposed so serious an obstacle to the successful introduction of machinery, as materially to have retarded the progress of the linen manufacture; and it is only within the last thirty years that the distaff and the hand-wheel have been entirely laid aside. Such rapid progress has, however, been made during that period in the improvement of flax machinery, that it has now attained to a state of perfection little short of that by which the cotton manufacture has been so long distinguished.

The double breaking machine.—The flax, when delivered at the mill, (having previously undergone such preparation as entirely to free it from its *boon* or woody particles, and to dissever its grosser filaments,) consists of long parallel fibres of different degrees of fineness, and varying from 26 to 36 inches in length. After having been duly assorted, it is divided into *stricks*, or small bundles, which are brought to this machine for the purpose of being cut or broken into two, three, or more lengths, according to the nature of the flax, the length of the staple, and the different sorts of yarn into which it is destined to be spun. It is most generally divided into three lengths, in which case the finest and best qualities of yarn are spun from the middle portion, on account of the superior strength as well as delicacy of the fibres at that part.

Fig. 1709 is a front elevation, and Fig. 1710 an end view of the breaking machine.

L L, the iron framework of the machine.

M M, the fast and loose pulleys.

N N, the cutter or breaker, fast upon the driving shaft. It is constructed of three wrought-iron rings, firmly bolted together between two cast-iron flanges; these rings have projecting points formed at regular intervals on their peripheries, and so disposed, when in combination, as to present numerous diagonal groups of cutters all round the circumference of the breaker. The cutters are of an elliptical form, and project about a quarter of an inch.

O O, a pair of grooved wheels fixed upon a horizontal shaft at a short distance on each side of the breaker, which revolves between them.

P P, a similar pair of wheels with projections on their circumferences, fitting into the grooves in the wheels O O, and revolving in the contrary direction.

Q Q, a set of compound levers, rods, and weights, for keeping the upper grooved wheels P P in contact with the lower O O. The purpose of these wheels is to bring the strick of flax under the action of the breaker, while the levers and weights Q Q maintain the requisite pressure upon it; the shaft carrying the upper grooved wheels being capable of moving vertically in the framing L L.

The opposite end of the machine is provided with a set of grooved wheels, weights, and levers, in all respects the same as those shown in Fig. 1709.

R R, a pair of spur-wheels fast upon the shafts of the upper grooved wheels and working into

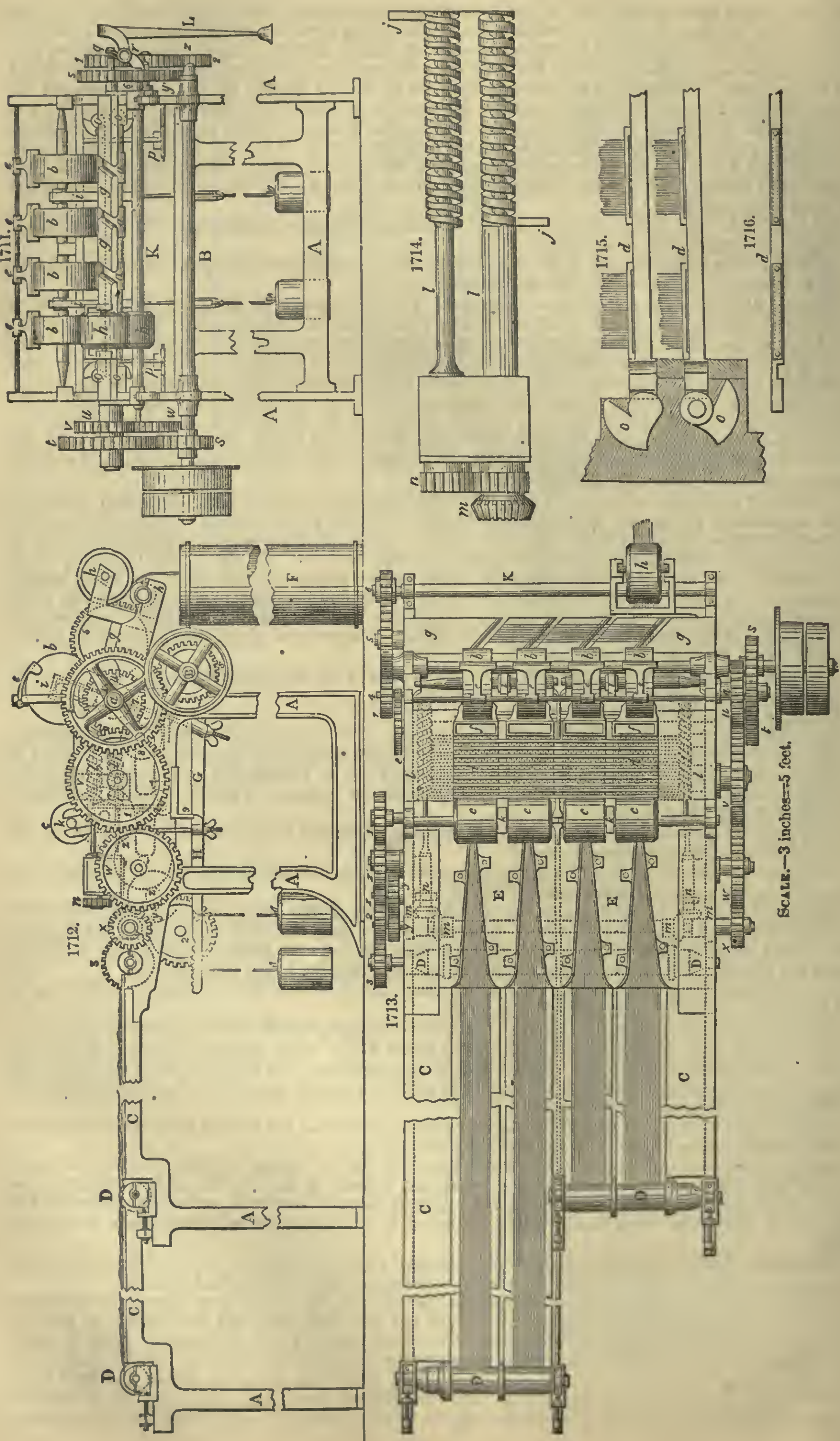
S S, a similar pair of spur-wheels fixed to the shafts of the lower grooved wheels O O, which is driven by a train of wheels at the opposite side of the machine. The wheels R R S S are made with teeth of a somewhat greater length than usual, to allow the flax to pass between the grooved wheels without disengaging the connection.

T T T, a train of spur-wheels and pinions by which the motion of the driving shaft is communicated, with a greatly reduced velocity, to the grooved wheels O O P P.

Action of the machine.—The strick or small bundle of flax is held in both hands, and laid transversely against the grooved wheels O O P P, which rotate slowly in the direction of the breaker. The latter, which makes about 300 revolutions per minute, tears or breaks it across by separating but not cutting the fibres. Two hands may be employed at the same time at this machine, one at each side.

The coarser having been thus divided from the finer portions of the flax, each sort is collected into a separate heap, and it is then ready to undergo the next process; namely, the hackling.

Hackling, and hackling machinery.—This is an operation of the utmost importance in the preparation of flax, as its successful accomplishment affects not only the quality but the quantity or *yield* of the yarn into which it is ultimately converted. The object proposed by it is threefold: First, the parting of the filaments into their finest fibrils; secondly, the separation and removal, with the least possible injury to the real fibres, of the *tow*, or short fibres which adhere to the former and bind them together; and thirdly, the equable and parallel arrangement of the long filaments. To accomplish these objects, the flax is drawn successively over two or more surfaces, thickly studded with sharp steel



1711. 1712. 1713. 1714. 1715. 1716.

SCALE.—3 inches=5 feet.

pins, or *hackle teeth;* the thickness of these, and their degree of approximation varying with the progressive stages of the operation.

In hackling by the hand, the operative wraps one end of the strick of flax firmly over his right hand, throws it upon the points of the coarse hackle, and draws it towards him, while he holds the left hand upon the other side of the hackle, in order to spread the flax, and to prevent it from sinking too deeply among the teeth. The other end of the strick is treated in the same manner; and the operation is repeated, first upon the coarse and then upon the fine hackles, until the fibres have been reduced to a sufficient degree of fineness, and, by careful handling, little more tow can be formed. To facilitate subsequent operations, the ends of the strick of flax should assume, at this stage of the process, an elliptical form when laid on a flat board. For this purpose the hackler wraps the end of the dressed strick round a pin shaped like a knife, and breaks or pulls away such of the fibres as by their length would tend to give it a pointed instead of an elliptical shape.

The hackling machine consists of two horizontal cylinders about 3 feet in diameter, on the peripheries of which are fixed hackles; the strength and number of these being varied according to the different stages of the operation. These cylinders are fixed upon shafts which are made to revolve with a considerable velocity in directions contrary to each other, both cylinders moving towards the centre of the machine. At each end of these cylinders is placed a large spur-wheel, geering with a central one, called the transfer wheel, situated between the two hackle-cylinders. All these wheels are fitted with a number of segments fixed to their inner surfaces and forming a species of drums, of a diameter considerably greater than that of the hackle-cylinders. Each of these drums contains a series of recesses, into which are fitted the clamps or *strick-holders* by which the flax is secured. The drums and hackle-cylinders are set with a considerable degree of eccentricity in relation to each other, so that the rim of the external drum may be further from the hackles at the back part of the machine, where the operation commences, than at the part where the strick is delivered to the transferring mechanism; this arrangement is requisite for the purpose of subjecting the end of the strick to the action of the hackles for a longer period than the middle, where the fibres are naturally much stronger, finer, and do not contain so much tow. The operation of this machine is as follows: the stricks having been firmly secured to their holders, the latter are inserted into the recesses of the first external drums; these rotate with a slow motion towards the centre of the machine, and the hackle-cylinders, revolving within them in the same direction but with a much greater velocity, dress the *under* sides of the stricks. On reaching the transfer wheels the strick-holders are, by an ingenious combination of slides and weighted levers, disengaged from the back cylinder, and pushed into the recesses on the transfer wheels; by these they are inverted and conveyed to the front cylinder and drums, which complete the process by hackling the *upper* side of the flax.

On being delivered at the front of the machine, which we have supposed to be the first, or *roughing* hackle, the stricks are conveyed by the attendant to the finishing machine, which is in all respects identical with that described, but is furnished with finer hackles. After passing through this the strick-holders are unscrewed, and the undressed ends drawn through them; they are again secured and returned to the roughing machine, where, by a repetition of the process already described, the opposite ends are finished. For further particulars of the hatchel, see rope manufacture.

The tow is cleared from the hackle-cylinders by means of revolving brush-cylinders situated at each end of the machine and underneath the centres of the former. From the brush-cylinders it is again transferred by doffing cylinders covered with card filleting; these latter are cleared by means of doffing knives, worked by eccentrics on the end of the brush-cylinders, the tow being delivered in broad sheets on the floor of the factory or into proper receptacles. The carding and spinning of the tow is performed by machinery similar to that employed in the cotton manufacture, though of considerably greater strength.

The spreading machine.—The next process undergone by the flax is its conversion into an endless band of parallel and rectilinear filaments, called a *sliver*, being the foundation of the future yarn. This is accomplished by the machine now under notice, which is fully delineated in Figs. 1711 to 1716.

Fig. 1711 is a front elevation of the spreading machine; Fig. 1712 a side elevation; Fig. 1713 a general plan; and Figs. 1714 to 1716 detached views, on an enlarged scale, of the spirals and fallers.

A A A, the cast-iron framework of the machine.

B B, the driving shaft, fitted with a fast and loose pulley.

C C, the feeding or *spreading* table; it is divided into two compartments, the one being considerably longer than the other, for the convenience of the attendants who spread the flax.

D D D, rollers situated at each end of the feeding-table; over these pass four endless leather straps, upon which the stricks of flax are spread.

E E, a polished iron plate, upon which are fixed the guides which serve to conduct the flax to the back or detaining rollers.

F, a cylindrical tin can, placed in front of the machine to receive the sliver.

a a a, the front or lower *drawing roller*.

b b b, the top drawing or *pressing* rollers, made either of wood or iron, and covered with leather

c c c, the back or *detaining* rollers.

G G, two weighted levers for imparting the requisite pressure to the top drawing rollers.

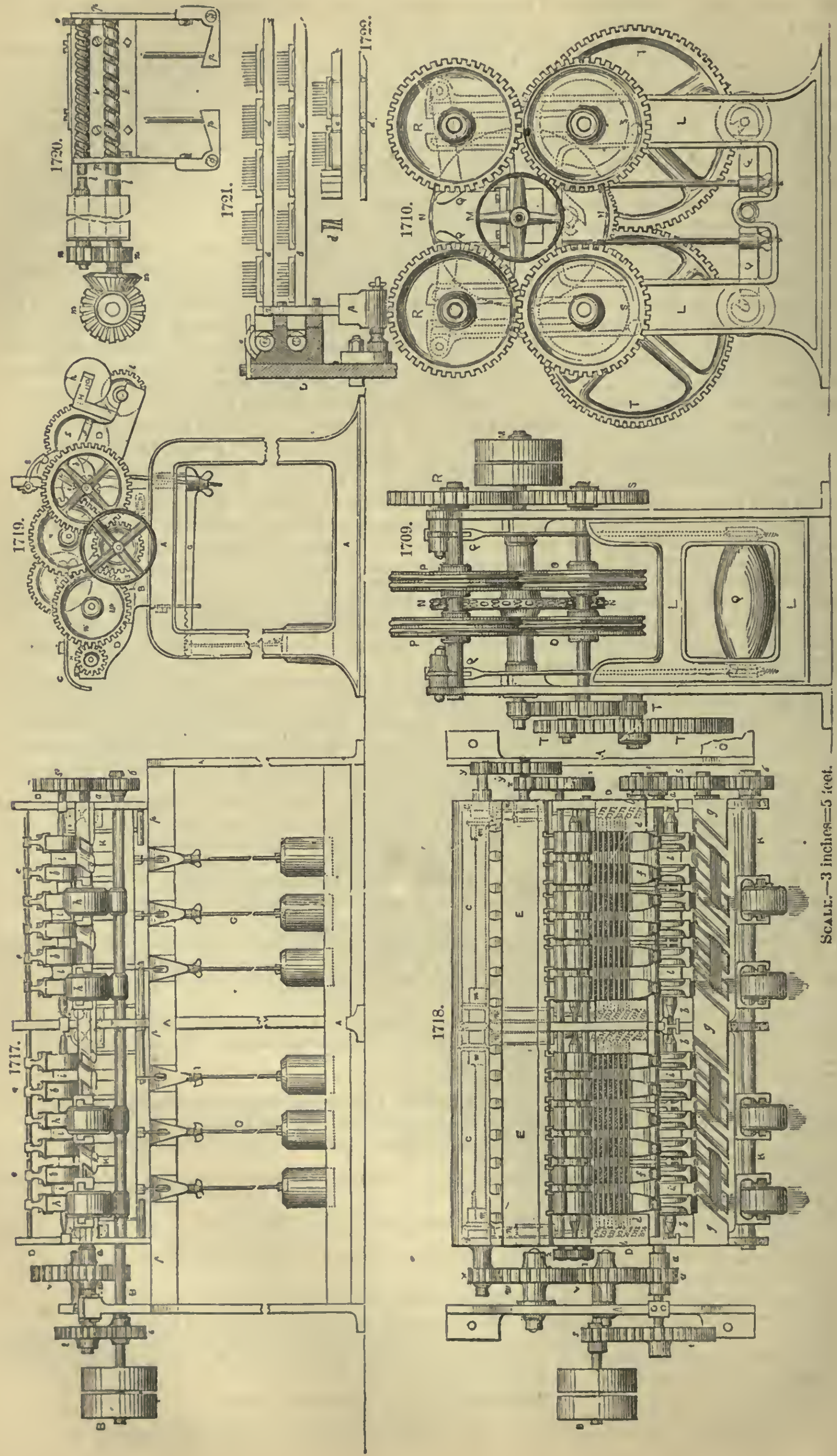
H H, two weighted levers bearing in a similar manner upon the top detaining roller.

d d, the *fallers* or *gill bars*, forming a sheet of advancing hackles between the detaining and drawing rollers; these are for the purpose of producing great regularity in the draught, and a perfectly parallel distribution of the fibres.

e e e, the *rubbers* for clearing the top drawing rollers from adhering fibres.

f f f, brass guides for conducting the sliver to the drawing rollers.

g g, the *sliver-plate*, formed with bevelled openings for the sliver to pass through towards


1720.
1721.
1722.
1710.
1719.
1709.
1717.
1718.
SCALE.—3 inches=5 feet.

h h, the *calender rollers*, by which the four slivers are compressed into one, and delivered in the form of a riband into the can F.

K, the calender rolling shaft.

i i, cast-iron hangers for transmitting the pressure of the weighted lever G to the top drawing rollers.

k k, are similar hangers attached to the lever H.

l l, the spirals or screws; into the spaces between the threads of which the ends of the fallers are inserted.

m m, two pairs of small bevel-wheels by which the lower spirals are driven from the *back shaft*.

n n, two small spur-wheels communicating motion from the lower to the upper spirals.

o o, the tappets or *cams* by which the fallers are elevated in succession from the lower to the upper spirals, and *vice versa*.

p p, small weighted levers for guiding the fallers between the threads of the spirals.

q, a small endless screw cut upon the extremity of the axis of the lower drawing rollers *a a;* it works into

r, a worm-wheel on the axis of which is another endless screw, driving a similar wheel, called the *bell-wheel;* at every revolution of this last wheel, a pin fixed into its rim acts upon a spring L, to the end of which a bell is attached. Thus the ringing of this bell serves to register the length of the sliver delivered into the can.

The following is the detail of the wheel work in this machine:—On the driving shaft B is fixed the spur pinion *s*, working into the wheel *t* on the lower drawing roller shaft; to this latter axis is affixed the wheel *u*, whose motion is communicated by the movable intermediates *v* and *w* to the change pinion *x* on the back shaft; the relative diameters of these wheels regulating the amount of *draught* or the degree of extension which the flax sustains in passing between the detaining and drawing rollers. The opposite end of the back shaft carries the pinion *y* working into the stud-wheel y', having on its boss the pinion *z*, which, by means of a movable intermediate z', drives the wheel $1'$ on the axis of the detaining roller. This train of wheel work is calculated to produce a nearly uniform surface speed of the rollers and the sheet of hackles.

A slow motion is communicated to the *sheet roller* D, over which the feeding bands pass, by means of the spur-wheel 3 working through an intermediate 2 into the pinion *z*.

A uniform velocity is imparted to the lower drawing and calender rolling shafts *a* and K, by a pinion 4 on the extremity of the former, working through an intermediate wheel 5 into a similar pinion 6 on the end of the latter.

And lastly, a revolving brush situated under the lower range of fallers, for the purpose of clearing away the dust, is driven by the stud-wheel 7, geering with the pinion 4, and having on its boss a small pinion working into the wheel 8 on the end of the brush-shaft.

Action of the machine.—The flax is placed in the sheet-iron guides behind the detaining rollers and along the endless bands or feed sheets, by laying down one handful after another, so that the points of the second strick reach to about the middle of the first, and thus preserve a uniformity of thickness in the feeding. By the motion of the machine it is introduced between the back rollers *c c*, and carried forward by the sheet of hackles *d d*, towards the front or drawing rollers *a a b b*, which, revolving at a velocity considerably greater than the former, lengthen or draw it out to a proportional extent; the hackles at the same time combing, separating, and straightening the fibres. The slivers from the four drawing rollers are then passed through the bevel slits in the sliver-plate *g g*, and united into one by the calender rollers *h h*, where they are subjected to a gentle pressure and delivered into the can F. This union of the slivers is necessary in order that the varying thicknesses of each may be compensated and perfect uniformity attained. When the can has received its destined supply, the ringing of the bell warns the attendant to break the flax, remove the can, and substitute another.

The drawing frame.—The next process in the preparation of flax consists in causing it to pass twice in succession through the drawing machine, for the purpose of still further increasing the fineness and uniformity of the sliver.

These machines, which are represented in Figs. 1717, 1718, and 1719, are in principle identical with, and in the details of their construction, very similar to, the spreading machine already described. They contain, as will be seen by the drawings, two sets of fallers and rollers, and the place of the feeding table and guides is supplied by a bent plate of polished sheet-iron C, extending across the entire breadth of the machine, over which the slivers glide in passing from the cans to the detaining rollers. These latter differ slightly from those used for the same purpose in the spreading machine; here they are three in number, and coupled together by small pinions, 1, 2, and 3, and disposed in a triangular form, the sliver being made to pass under the first, over the second, and under the third. With these exceptions there is no essential difference between the present machine and that last described, and as we have been careful to designate the same or analogous parts in both by the same letters, it will be unnecessary to repeat the description.

Spiral or screw gill.—Figs. 1720, 1721, and 1722 give a representation of a very interesting and important piece of mechanism which enters largely into the construction of modern flax machinery. This ingenious contrivance has, in a great measure, superseded all former modes of effecting the same object, which is the combing and separating the fibres of the flax, in order to facilitate the drawing and to give uniformity to the sliver.

The fallers or hackle bars *d d*, Fig. 1721, are supported at both extremities by the horizontal steel guide rails *k k*, screwed to the insides of the sockets in which the spirals or screws *l l* work; these sockets being bored in projecting parts cast upon the stands D D. The lower screw is driven from the back shaft by a bevel-wheel and pinion *m m'*, and a small spur-wheel *n*, on the back of the bevel pinion, works into a corresponding wheel on the top screw, driving both screws at equal velocities but in contrary directions. In the sides of the sockets in which the screws revolve, openings are formed,

parallel with their axis and coinciding with the surfaces of the guide rails *k k*; through these openings the ends of the gill-bars, (which are steeled and bevelled to compensate for the angle of the threads,) are inserted into the helical grooves of the screws. Thus the rotary motions given to the spirals cause the fallers to be driven along the guide rails in a vertical position, and with a uniform simultaneous movement; the top sheet in the direction of the drawing rollers, and the lower towards the detaining rollers.

On reaching the front part of the machine, close behind the drawing rollers, the fallers are depressed and put out of operation by means of the rotary cams *o o*, fixed to the ends of the top screws; being guided vertically downwards between the ends of the upper guide rails and the weighted levers *p p*. They are thus engaged in the threads of the lower screws, which carry them to the opposite end, where similar cams *o o*, and weighted levers *p p*, raise them successively into their original position on the upper guide rail, where they are traversed forward as at first. It is usual to make the lower spiral with the threads considerably wider than those of the upper, which arrangement diminishes the total number of fallers requisite for the due performance of the work.

Self-regulating spiral roving machine.—Fig. 1723 presents a general elevation of the entire machine as seen in front; one of the plates which protect the spiral pinions being removed in order to show the mode of giving motion to the spindles, flyers, and bobbins.

Fig. 1724. A corresponding general elevation of the back part of the roving frame exhibiting the cone and differential movements, and by the removal of one of the covering plates, exposing a part of the back shaft and geering for working the fallers.

Fig. 1725 is an end elevation, showing the principal geering employed in this machine.

Fig. 1727 is an elevation, partially sectioned, of portion of the spindle rail or beam, and Fig. 1728 is a plan corresponding.

Fig. 1729 is an elevation, also partially sectioned, of part of the bobbin lifter with its attached geering, and Fig. 1730 is a plan of the same.

Fig. 1726 is a transverse section of the machine, exhibiting some of its internal arrangements, and showing the course of the sliver from the cans to the bobbins.

Fig. 1731 is an elevation of part of one of the stands, showing the slides, springs, and weighted levers used for defining the course of the fallers.

Fig. 1732. An elevation and plan of the contrivance for transmitting motion to the axis of the spirals on the bobbin rail.

Fig. 1733. A cross section of a part of the machine, showing the apparatus for maintaining constant tension upon the strap driving the cone pulley of the traverse and equational bobbin motions.

A A, the driving shaft, situated towards the back of the machine and extending throughout its entire length.

B B, a shaft parallel and near to the driving shaft, extending from the centre to one end of the machine. It carries a spur-wheel at each extremity, one of which is commanded by the equational bobbin motion, while the other, by means of a peculiar arrangement of geering, to be hereafter described, transmits the motion to the spiral shaft on the bobbin rail.

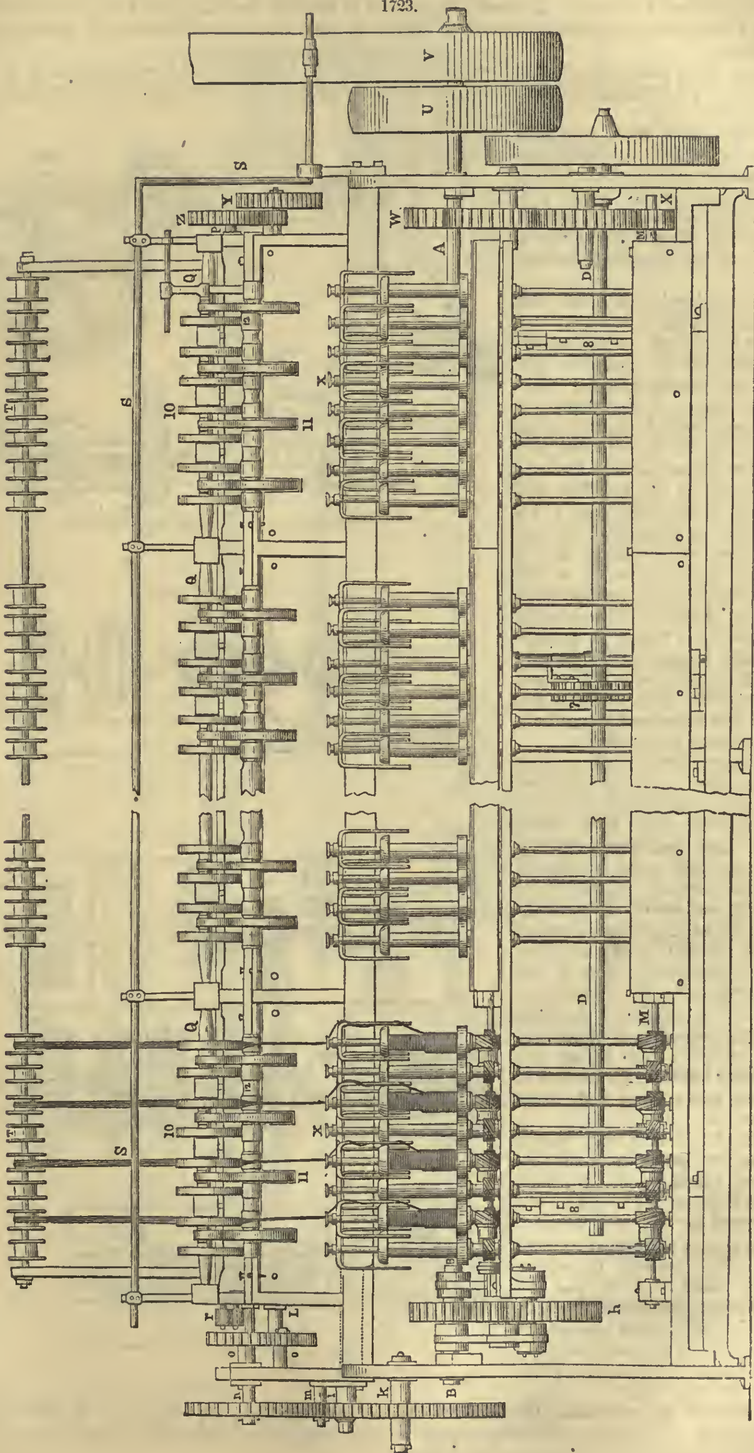
C C, the mangle pinion shaft worked by a train of bevel-wheels from the cone shaft, and, through the mangle wheel, situated at one end of the machine, close to the driving pulleys, working.

D D, the mangle wheel shaft extending the whole length of the machine, and carrying pinions working into racks 8, 8, 8, attached to vertical slides; these slides are furnished with projecting arms fixed to the bobbin rail, which is traversed up and down by the mangle wheel; causing the flyers to wind the roving between the flanges of the bobbins, with all the regularity of a screw. Counter-balance weights 1, 1, 1, attached to the bobbin lifter by means of chains passing over pulleys, serve to relieve the racks from all unnecessary strain.

E, a short shaft situated at the back of the machine, and driven by a train of spur-wheels from the driving shaft at the same velocity as the latter. Upon this shaft is suspended a species of frame, fitted to slide longitudinally upon it, and carrying two pulleys and a weight at the extremity; the first pulley being adapted to rotate with the shaft E, by means of a long slot and sunk feather, and the other being merely a conical friction roller, for the purpose of maintaining a constant tension upon the strap driving the cone F, Fig. 1733. The frame, with its appendages, is traversed along the shaft by means of a weight 2, situated at the opposite end of the machine, and attached by a chain and adjustable rod to the frame and to a rack working in a slide fixed to the back of the roller beam, Fig. 1726. This rack is serrated on both edges, the teeth of the upper alternating with those on the lower edge, and the pawls are alternately disengaged at every revolution of the mangle wheel in such a manner as to allow the drag weight to advance the rack and pulley frame by half the distance between two contiguous teeth. The mechanism by which the pawls are disengaged is as follows:—At the back of the rack slide a short rectangular bar is fitted to slide vertically, having two projecting pins acting upon the points of the clicks, Fig. 1726. This bar is worked by the end of a lever inserted through its lower extremity, and having its fulcrum under the roller beam; to the other end is attached the vertical rod 5, carrying two adjustable catches 4, 4, which, at every alternate movement of the mangle wheel, are struck by an arm 6 extending from the rack 7. Thus one of the pawls is constantly in geer to prevent the rack and attached pulley frame from being drawn beyond the prescribed limits for each stroke. The lower pawl is kept pressed against the rack by a counter-weight 3, while the upper one merely rests on it by its own gravity. The pitch of the teeth on the rack must be varied according to the degree of fineness of the roving.

F, the cone driven by a strap belt from the pulley on the shaft E, and communicating a gradually retarded motion, at once to the bobbins themselves and to the traverse of the bobbin rail; the velocity of the spindles and flyers remaining constant. This is necessary in order to compensate for the continually increasing diameter of the bobbins as the roving is wound upon them. The cone is set at a

1723.

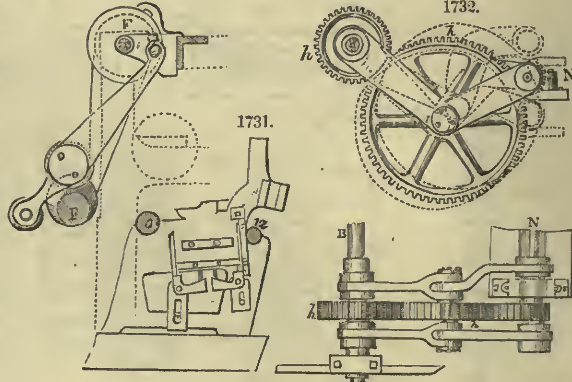


SCALE.—3 inches=4 feet.

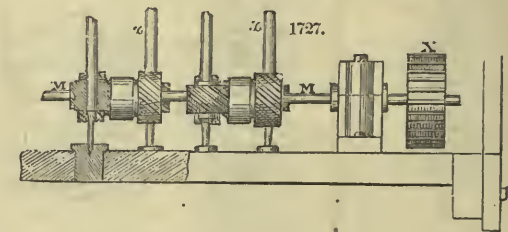
slight inclination, in order to allow the belt to act upon a greater part of its periphery towards the apex than towards the base where, on account of the increased diameter, this precaution is less necessary to ensure the rotation of its shaft. A lever handle (seen in the end elevation, Fig. 1725,) is attached to the carriage of the cone shaft, for the purpose of raising its outer extremity previously to winding back the pulley frame.

G H, two short shafts situated towards the centre of the machine, and carrying geering to be hereafter specified, for transmitting the motion of the cone shaft F to the traverse and equational bobbin motions respectively.

1733. 1732. 1731.



1727.



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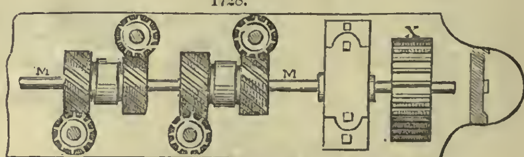

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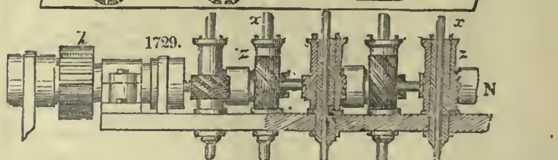
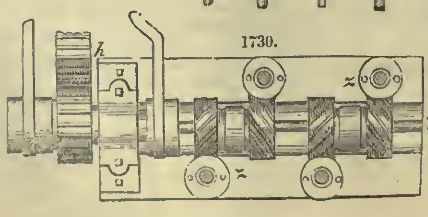


1730.



I, a hollow boss fitted to rotate upon the driving shaft A, with a motion independent of that of the latter, and carrying at one end a spur pinion working into a wheel on the shaft B, and at the other a bevel-wheel, being part of the equational bobbin motion.

K is a similar bevel-wheel fast upon the driving shaft A.

L L, the back shaft traversing the entire length of the machine, and carrying the bevel-wheels for working the mechanism of the fallers.

M M, a longitudinal shaft working in bearings on the spindle rail, and carrying the spiral pinions for conveying motion to the spindles and flyers, Figs. 1726, 1727, and 1728. The spindles are disposed in two rows, so that each spindle in the back range stands opposite to the interval between two in the front range. The object of this distribution is economy of space, as the machines would require to be greatly longer if the spindles stood all in one line. The shaft M is situated between the two rows, and drives both rows in the same direction.

N N, a longitudinal shaft working in bearings on the bobbin rail, and carrying the spiral pinions for working the bobbins, Figs. 1726, 1729, and 1730. The spindles pass through brass sockets fixed to the bobbin rail to hold them steady as the latter traverses up and down. These sockets serve also as pivots for the spiral pinions to revolve upon; it being understood that the motion of the bobbin spirals is totally independent of that of the spindles. A small flange on the top of each spiral carries two projecting pins fitting into corresponding holes in the bottom of the bobbins, and causing both to revolve together.

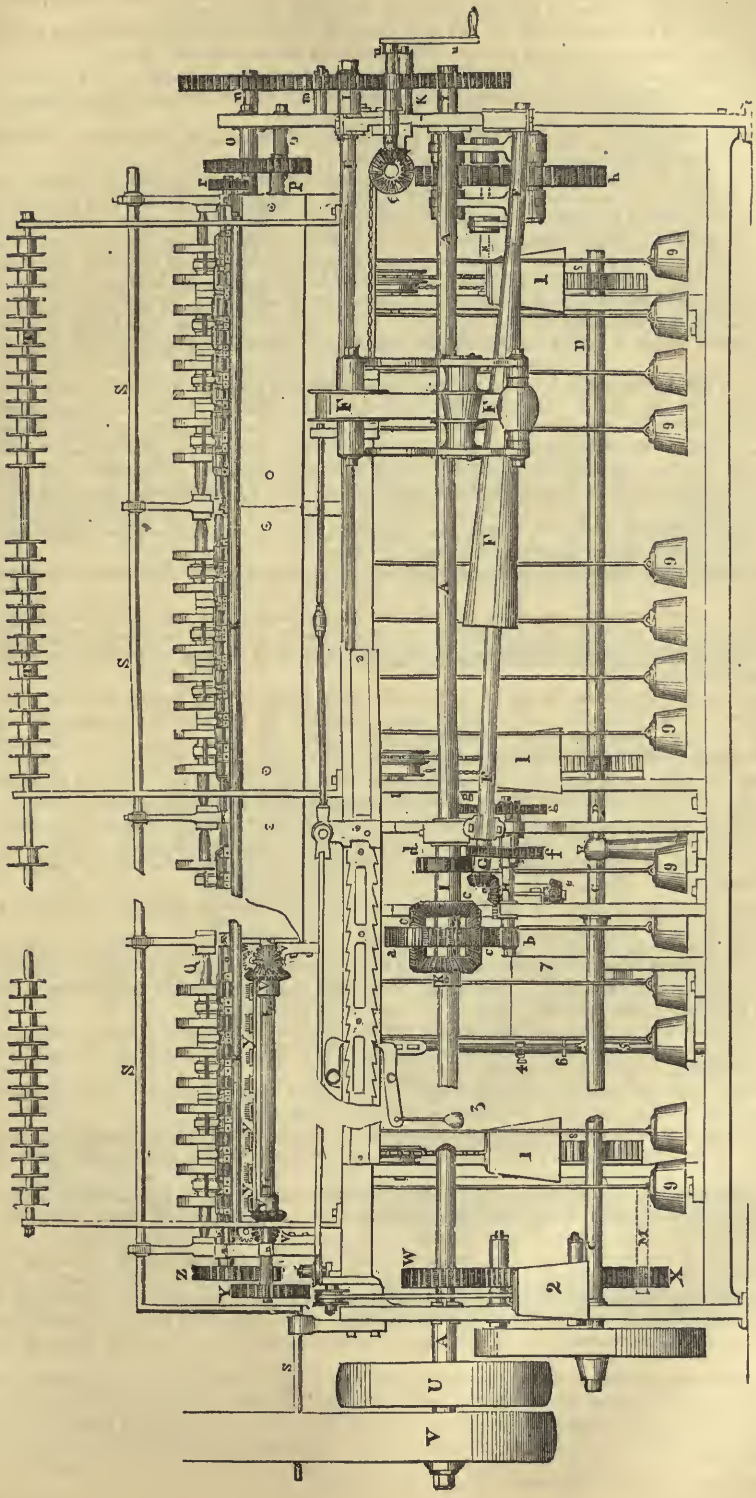
O P, the back detaining rollers having the iron pressing rollers between them, which are cut into short lengths, and are carried round by the friction caused by their own gravity.

Q Q, the axes of the pressing or top drawing rollers marked 10, which are usually made of wood, and are pressed against the lower drawing rollers 12, 12, by hangers 11, 11, resting in necks cut in the axes and attached to weighted levers 9, 9, passing under the roller-beam.

R R, a slender rod extending the entire length of the machine, for conducting the slivers to the detaining rollers. They pass under this rod, and slide over a polished sheet-iron plate covering the back shaft and bevel geering for driving the gill screws

S S, a rod by which the attendant is enabled at any part of the machine to stop or set it motion.

1734.



Scale.—3 inches=4 feet.

T T, are a set of friction pulleys placed upon a rod surmounting the machine, for the purpose of guiding the slivers as they are drawn out of the cans by the action of the machine.

U V, the fast and loose pulleys on the end of the driving shaft for starting and stopping the machine

W W W, is a train of spur-wheels conveying the motion of the driving shaft A to

X, a spur-pinion on the end of the shaft M, which drives the spindles and flyers with a uniform motion

Y Z, the draught geering between the drawing and detaining rollers, the particulars of which will be given below.

a b c c and *d*, are spur and bevel wheels and pinions, the combination of which forms the differential motion for driving the bobbins.

Supposing that the large spur-wheel *a*, which, through the pinion *b*, receives its motion from the cone, were driven at the same velocity as the driving shaft A, then it is obvious that no motion whatever would be imparted to the bobbins. On the other hand, if the wheel *a* were held absolutely immovable, the bevel K, which is fixed upon the driving shaft, would convey, through the pinions *c c*, a motion equal to its own, though in the contrary direction, to the boss I and attached geering; consequently, in the case we have last supposed, the motion communicated to the bobbins would be uniform. Hence, by combining the two extreme cases, and supposing the wheel *a* to be driven in the direction of the driving shaft, but with a slower velocity, it will be understood that the boss I will be made to revolve at a speed which, if added to that of the wheel *a*, will be exactly equal to that of the driving shaft A.

Thus, when the driving strap is at the apex or starting point of the cone F, the wheel *a* is at its maximum velocity, and the boss I with the train of wheels to the bobbins at their minimum, causing the flyers, which revolve at a considerably greater *uniform* speed, to coil the given quantity of rove upon the bobbins; then as the strap advances towards the base of the cone, (every point in this advance being simultaneous with the commencement of a fresh layer of roving,) the speed of the wheel *a* is diminished, causing that of the boss I to *increase* in the same ratio, and thus approximating the speed of the bobbins to that of the flyers, at every alternate motion of the traverse. In this way the irregularity due to the varying diameters of the bobbins is compensated, and a uniform very slight tension maintained upon the slivers between the flyers and the drawing rollers.

e e e, a train of bevel-wheels and pinions for conveying the motion of the short shaft G to the mangle pinion shaft C.

f g g, a train of spur-wheels and pinions (including change pinions) for conveying the motion of the cone F, at once to the traverse and equational motions. It is obvious that to preserve the regularity of the winding, the speed of the traverse or copping motion, as well as that of the bobbins themselves, must be progressively retarded.

h h h, a train of spur-wheels for conveying the differential motion to the bobbin shaft N. The pinion *d* on the boss I works into a wheel fixed to the end of the shaft B; this shaft has another spur-wheel *h*, Figs. 1725 and 1732, upon its opposite extremity, which geers with *h* an intermediate wheel suspended in a joint formed by the meeting of two pairs of arms; one of which have their centre of motion on the shaft B, and the other upon the shaft N. Thus, when the latter ascends and descends in obedience to the traverse motion, the arms move in a radial direction round their respective centres, and consequently the suspended wheel *h* is kept constantly in geer both with the wheel on the end of the shaft B and with the pinion on the shaft N. This will be clearly understood by observing the dotted lines in Fig. 1732, which denote the different positions of the bobbin lifter, and the corresponding positions of the arms and intermediate wheel.

i k l m, a train of spur-wheels for conveying the motion of the driving shaft to the shaft E working the cone motion, Fig. 1725.

n, is a spur-wheel on the end of the drawing roller, also working into the movable intermediate *k*, which thus commands the drawing, the bobbin, and traverse motions. The train *i k n*, is called the *twist geering*, and its object is to vary the speed of the front roller while the speed of the spindles remains the same, and thus to put more or less twist into the rove as may be required.

o o p, a train of wheels between the drawing rollers and the back shaft—*p* being a change pinion; these, together with the train Y Z, at the opposite end of the machine, constitute the draught geering.

r r, small pinions connecting the detaining rollers together.

t u, a handle and small bevel-wheels working a barrel round which is coiled a chain attached to the pulley frame for winding the rack, &c., towards the apex of the cone F.

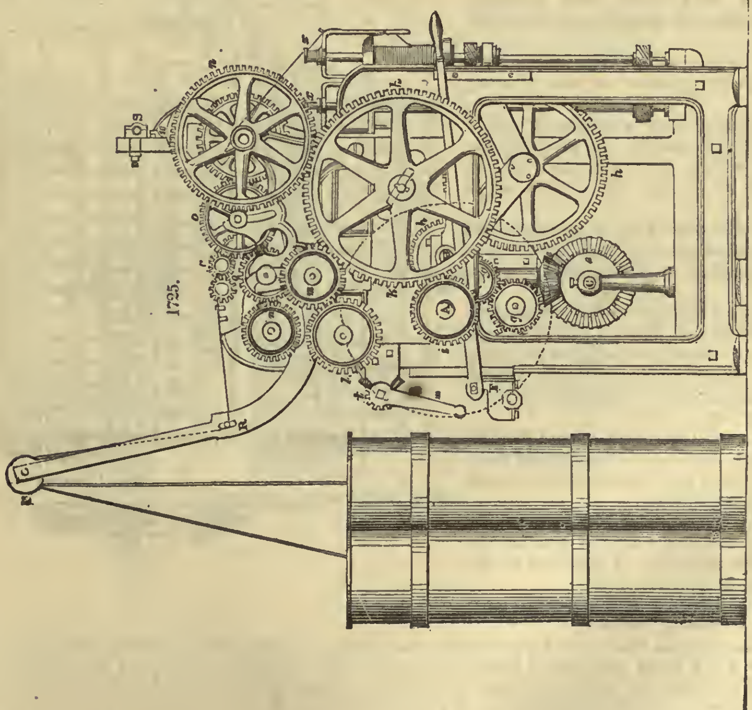
v v w w y y, the fallers and geering for working them, as minutely detailed in a preceding description.

x x x, the flyers fixed upon the top of the spindles for twisting, guiding, and winding the rove upon the bobbins.

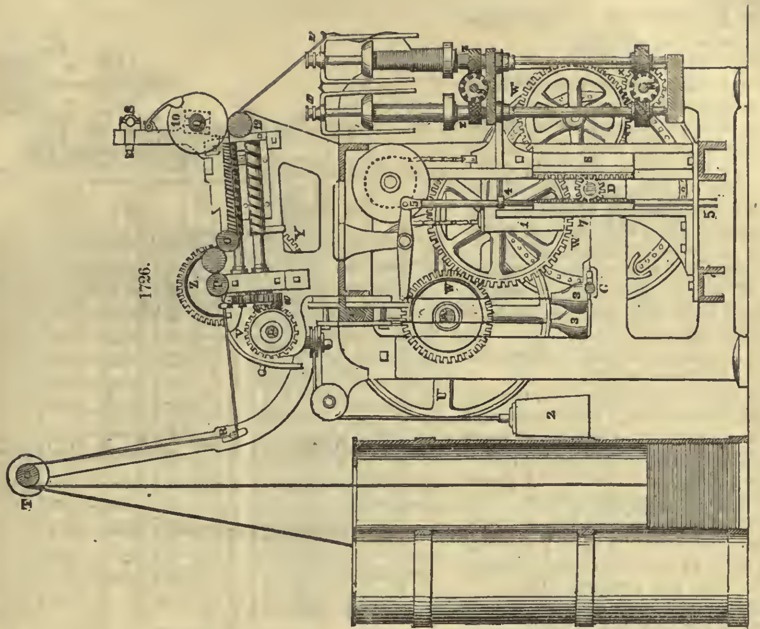
The wet spinning frame.—With the exception of the hot-water trough and its adjuncts, this machine bears a close resemblance to the *throstle frame* of the cotton manufacture, and like it, is employed for the completion of the yarn, after being subjected to the processes of drawing and roving.

Although the principle of its operation be, for the most part, the same as that of the roving machine, it is much less complicated than the latter, inasmuch as it dispenses with the gill apparatus, (which is, of course, only applicable to parallel slivers,) and with the equational bobbin motion, which, in the present instance, is rendered unnecessary by the circumstance of the yarn itself having attained a sufficient degree of cohesive force to enable it, with the aid of a simple contrivance, to regulate the drag upon the bobbins.

A very important improvement in the spinning of flax is the use of the hot-water trough, through which the rovings are caused to pass in the act of spinning. By this means, the glutinous matter adhering to the fibres is thoroughly dissolved, and a much finer, smoother, and more uniform thread than could otherwise have been possible, is produced. There is an improvement in the method of driving the spindles, by which one tape is made to communicate motion to four spindles, and another in the method of working the traverse motion, as seen in the figures.



1725.



1726.

Fig. 1734 is a front elevation, broken in the middle, for the purpose of exposing part of the geering for working the traverse motion.

Fig. 1735 is an elevation of the *geering* end of the machine; and Fig. 1736 is a transverse section of the entire machine.

Literal References.—A A, the frame ends or standards of cast-iron.

B B, the middle support.

C C, longitudinal beams of cast-iron, on which are supported

a a, the stands or framing of the rollers. The bottom or drawing roller journals are fixed, while the top or detaining roller journals slide on the upper part of the stands, and are regulated by screws, (see dotted lines in Fig. 1736,) so as to adapt the *reach* or distance between the drawing and detaining rollers to the various lengths of fibres. This distance should always be a little more than the average length of the filaments.

b b, the bottom or drawing rollers, usually called the *front* rollers.

c c, the top or detaining rollers, usually called the *back* rollers. Both front and back rollers are made of brass cast upon a wrought-iron shaft or axle, and fluted.

d d, the *saddles* for retaining the pressing rollers in their proper places. The bushes or bearings of the top pressing rollers are made to slide upon projecting arms, in order to suit the various lengths of reach. The top pressing rollers are generally made of brass and the bottom of box-wood, and both are fluted.

e e, are bolts fitted with adjusting thumb-screws for attaching the saddles *d d*, to

f f g g, levers with weights for giving the requisite pressure to the pressing rollers.

h h, cranked axles extending the entire length of the machine for relieving the pressing rollers from the strain of the weighted levers when the machine is at rest.

i i, ratchet-wheels fixed upon the end of the cranked axles for maintaining them in the position in which they may be placed.

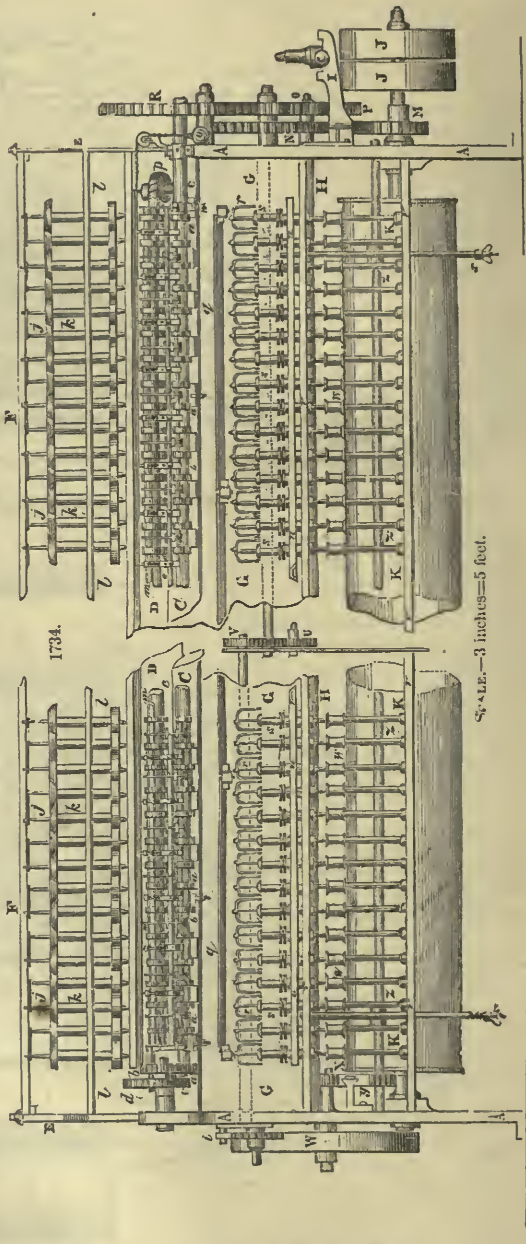
D D, the wooden troughs surmounting the machine, and through which the rovings pass before reaching the detaining rollers. These troughs are supplied with hot water, and kept at a high temperature by steam from a boiler.

E, the *creel* in which the roving bobbins are placed vertically, in alternating rows.

F, a wooden rail surmounting the creel, to which are attached

j j, the slender sheet-iron supports for the top of the roving bobbin spindles, the lower ends revolving in footsteps on the top of the trough, Fig. 1736

k k, the bobbins, as filled with loose yarn by the roving machine.



1734.

SCALE.—3 inches=5 feet.

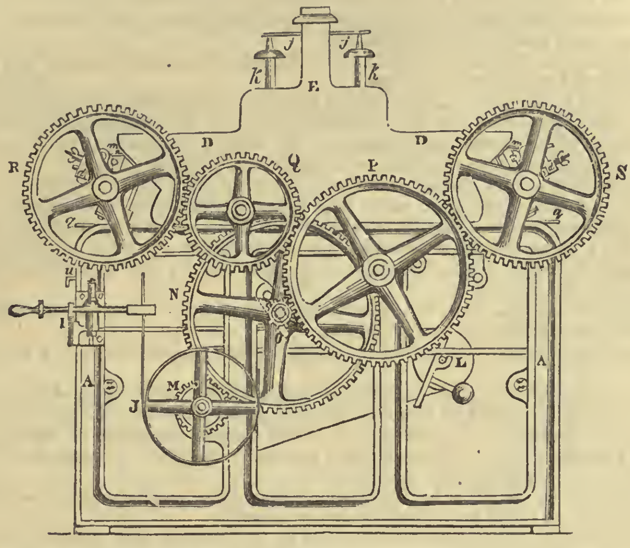
l l l l, longitudinal brass rods for conducting the rovings into and through the troughs D D.

m m, is a flat brass rod, placed immediately above the detaining rollers, and extending the entire length of the machine; opposite to each boss of the detaining rollers an indentation is cut in the rod *m*, for the purpose of guiding the rovings. A small endless screw is cut on the end of the detaining roller shaft, and geers with a worm-wheel *p*, Fig. 1734, which works on a stud fixed to the beam C, and has a small *heart-wheel* formed upon its upper surface. A small steel pin *n* is fixed to the end of the rod *m*, and is pressed against the heart by a drag-weight *o*, attached to it by a chain passing over a small pulley. As the roller revolves, it produces a slow motion of the heart causing the rod *m m*, to traverse

nearly the whole length of the boss, and thereby preventing the roving from wearing the surface of the rollers unequally.

q q, the thread-plates or guides, having small notches opposite to each bobbin through which the threads pass on their way from the drawing rollers to the eyes of the flyers. These plates are made in separate lengths as may be convenient, and are hinged in order to enable the bobbins to be inserted in o or withdrawn from the spindles.

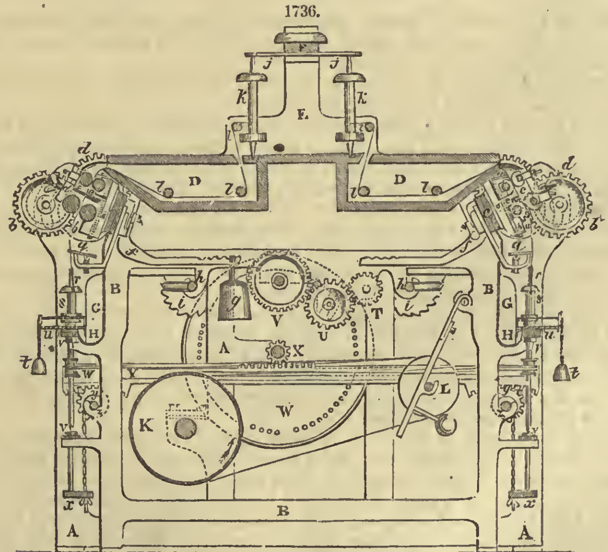
1735.



G G, are sheet-iron linings extending from the beam C to

H H, spouts formed under and within the rows of bobbins. These linings and spouts serve to collect and withdraw the water which is thrown off by the centrifugal force of the bobbins.

1736.



r r, the flyers for guiding and winding the yarn on

s s, the bobbins, formed with a species of pulley on their lower flanges. In this machine the bobbins are not driven independently of the spindles, for a reason which we have specified in our introductory remarks. The natural tendency of the bobbins to wind on the yarn regularly is assisted by the following contrivance:

t t, are drag weights, attached by pieces of string to loops on the back of the bobbin lifter; these cords pass across to a plate with a serrated edge fixed to the front of the bobbin lifter, and press against

the grooves formed in the lower flanges of the bobbins. The friction thereby occasioned, which may be varied by changing the length of leverage at which the weights act, gives the bobbin the requisite retardation for winding on the yarn.

u u, the bobbin beams or lifters supported by the traverse rods *x x*, which are attached to bosses upon the traverse shaft *z z*, by chains furnished with adjusting thumb-screws for adapting the bobbins to the height of the flyers.

v v, are the spindle rails or beams, in which are inserted the steps and collars for the spindles to run in.

w w, the spindles themselves, with their driving wharves or pulleys fixed to them.

I, is a bracket upon which works the strap-guide for starting and stopping the machine.

J J, the fast and loose pulley fitted to the end of

K K, a long cylinder constructed of tin plates and extending the entire length of the machine, forming a continuous drum for driving the spindles.

L, a balance pulley round which the tape passes for driving the spindles, and which keeps it at the proper tension. The tape passes over the cylinder K, then over the balance pulley L, and round two spindles on each side of the frame, thus causing one belt or tape to drive four spindles. Previously to the introduction of this method, each spindle was impelled by a separate tape.

M N O P Q R S, a train of spur geering, (O being a change pinion,) constituting the twist geering and conveying motion from the driving shaft to the front rollers on both sides of the frame.

T U V, a train of spur-wheels situated at the middle of the frame, and constituting part of the traverse geering. T is a pinion fast upon the end of the shaft which carries the intermediate twist wheel P, and which has a bearing in the middle support B. This wheel works through the intermediate U, into V upon the mangle pinion shaft.

W is the mangle wheel situated at the opposite end of the frame to the twist geering, and actuated alternately in both directions by the mangle pinion.

X, a small spur-pinion fixed to the axis of the mangle wheel, and working into a rack formed on the top edge of

Y, a cast-iron horizontal bar working transversely in slides bolted to the inside of the end framing A A. Each extremity of this bar is formed into a radial rack; these work into the eccentric spur-wheel *y y*, fixed upon the traverse shafts *z z*, imparting to the latter a *graduated* motion of rotation, which is communicated to the bobbin lifter by the mechanism previously described; causing the flyer to wind the yarn upon the bobbin in a slightly spherical form.

a′ b′ c′ d′, a combination of wheels forming the draught geering, precisely similar to the draught geering in the other machines which have come under our notice.

FLOATING BRICKS, in imitation of those made by the ancients, were formed by M. Fabbroni, out of a material which consisted of 55 parts of siliceous earth, 15 of magnesia, 14 of water, 12 of alumina, 3 of lime, and 1 of iron: this kind of brick does not become altered by fire, being infusible, and although it loses $\frac{1}{8}$ part of its weight, it is not in any way diminished in size: as these bricks are found to float on water, they have been very much used where lightness of construction was desirable. See Fire-Bricks.

FLOATING SECTIONAL DOCKS, Messrs. Burgess and Dodge, New York, patentees. These docks are very powerful, being capable of lifting vessels of upwards of 2,000 tons burden, and are executed at a comparatively small cost, being chiefly of timber.

These docks, instead of being fixed, and in one position, like the marine railway and screw docks, may be towed to any vessel within a convenient distance.

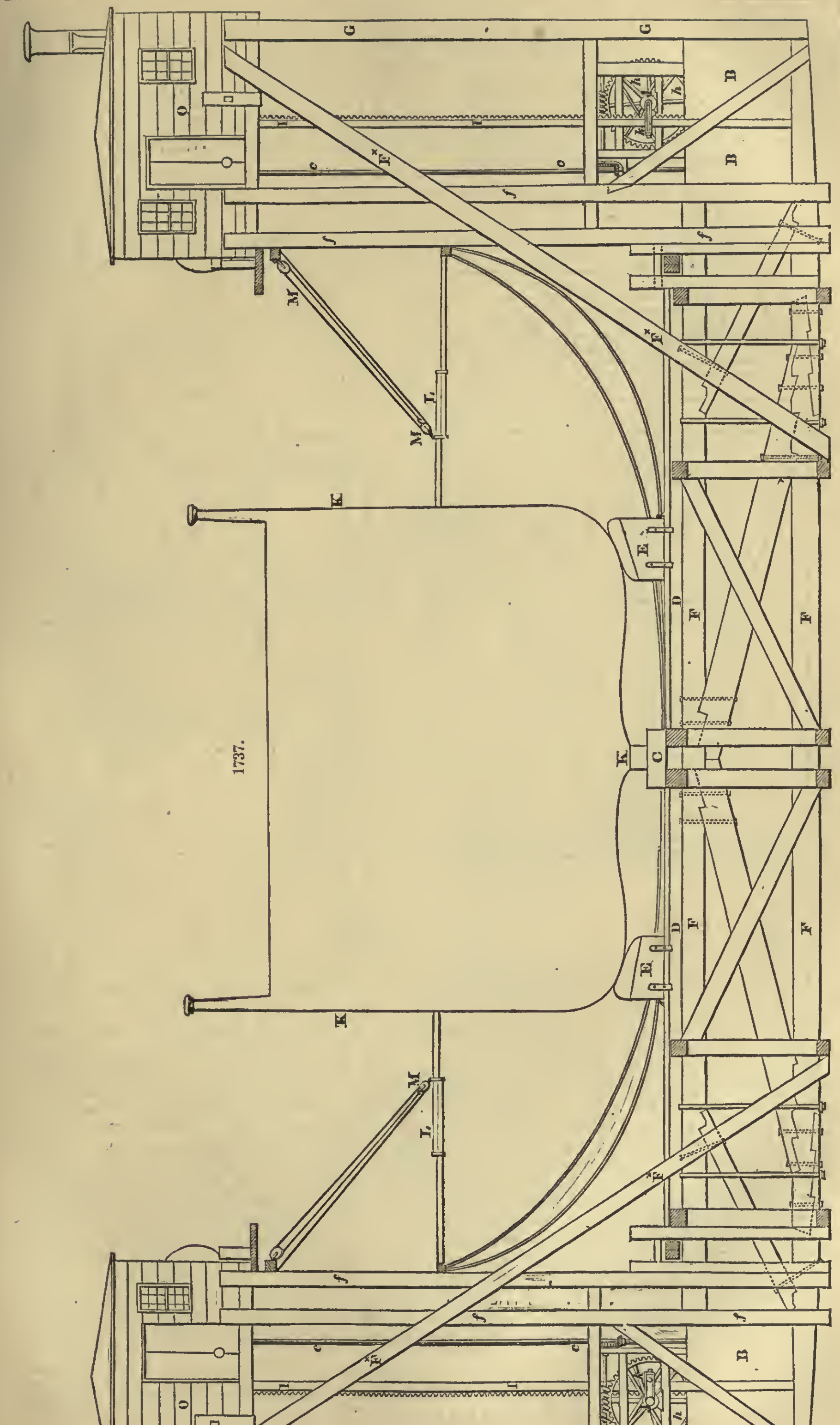
Suppose that a ship is sunk, say in 5 fathoms water, it may be raised to the surface by hogsheads, or slung by any of the usual modes; and, once got up to the surface, the sectional floating dock can be readily introduced beneath it, and the whole towed together to the landing or shipwright's wharf.

The sectional floating dock derives its name from its consisting of distinct sections of timber framing in the form of a floating dock, into which ships can enter. In the sections on each side are balance tanks raised and lowered by means of a rack and pinion, and also tanks, which, by being filled with water, cause the dock to sink, and by the water being pumped out enable it to be raised to any required height out of the water, the ship resting on the platform within. On the top of the sections is machinery for working the racks and pinions and pump-work.

Such is the general principle of the contrivance. Now to detail the construction. According to the size of the vessel to be raised, any number of sections, more or less, may be used, as convenience suggests. Each section is 92 feet broad externally, and 64 feet internally, and 23 feet long. The section is 38 feet high externally, exclusive of engine house, and 28 feet high internally to the top of the standards. The dock, it will be seen, is neither more nor less than a large floating timber vessel, and is constructed of beams strongly bolted together.

Each section may be considered as consisting of three parts, two lateral scaffoldings or framings of standards within which the balance tanks run, and a central platform connecting them. The object of the lateral framing is to enable the balance tanks B to be run up and down, and to prevent the machines from coming in contact with the water. Each lateral portion, Fig. 1737, consists of two external standards G, 36 feet high and 12 inches square, and of four internal standards *f f*, 37½ feet high and 12 inches square. These standards are at the bottom secured to the outside truss girders F, and on their tops carry a platform on which the engine apparatus is placed. The standards are bound together by proper tie-pieces, and are further secured to the outside truss girders F by a 12-inch beam 44 feet long, F*. At the bottom of each lateral framing is a flooring on which rests a balance tank B, 19½ feet long, 10 feet broad, and 8 feet deep, being of a capacity of about 1500 cubic feet. The total capacities of the fourteen tanks would therefore be 21,000 cubic feet. Besides these are water tanks within the platform in which the pump rods *t′* work.

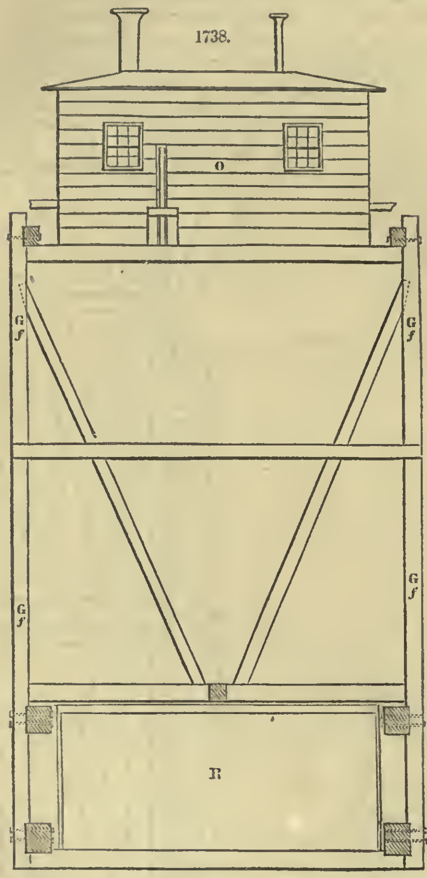
The platform is about 10 feet deep, and on the upper surface consists of two outside truss girders F F, being about 70 feet long and 17 inches across, composed of two beams scarped together. Between these



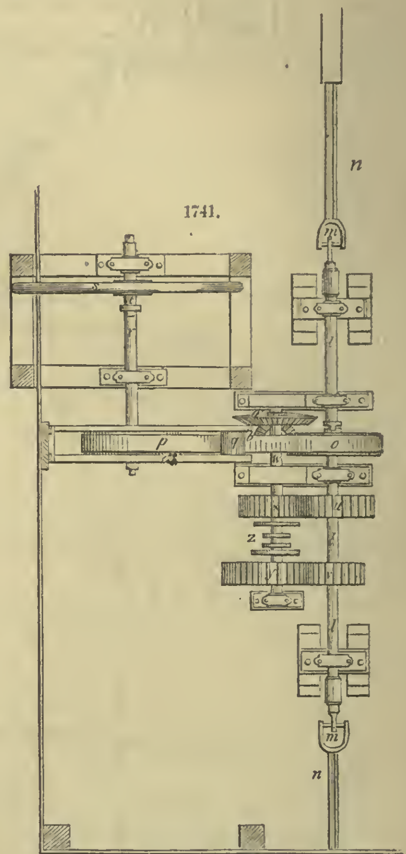
1737.

are a cross beam, 7 inches square, in the centre, secured to the keel beam P, and a cross beam on each side D D, 9 inches square, for carrying the chock blocks E, and secured to the keel beams P. These cross beams rest on joists or tie-pieces, 10 inches square. In the centre across are the two keel beams P P, 24½ feet long and 12 inches square, and which carry five keel blocks C. This upper platform rests on the foundation truss girders F, by means of posts and timbers scarfed in, and is further secured by four stout iron ties. The bottom truss girder F 2 is 93 feet long, and formed in three portions, well scarped, tied, and bolted together. These bottom truss girders extend under the lateral framings, knitting together the whole structure

1738.



1741.



The sections are connected together, in case of need, by double tie beams, which can be readily slipped out, by withdrawing the nuts and screws by which they are secured.

On the cross beams D D, Fig. 1737, on each side is a rack and pawl, enabling the chock blocks E to be readily moved, and secured by means of tackle. The chock blocks are 4 feet high and 3 feet 9 inches wide. These receive the bottom of the ship; but in order to steady the sides there are side supports on each side L L, worked by block and pawl M, so as to make the ship firm to the inner standards *f f*.

The object of the balance tanks B is to keep the dock steady and in an upright position. They contain no water, and it is only necessary to keep them depressed to the level of the water, either in sinking or raising the dock, and their resistance keeps the whole dock, with the ship, perfectly steady.

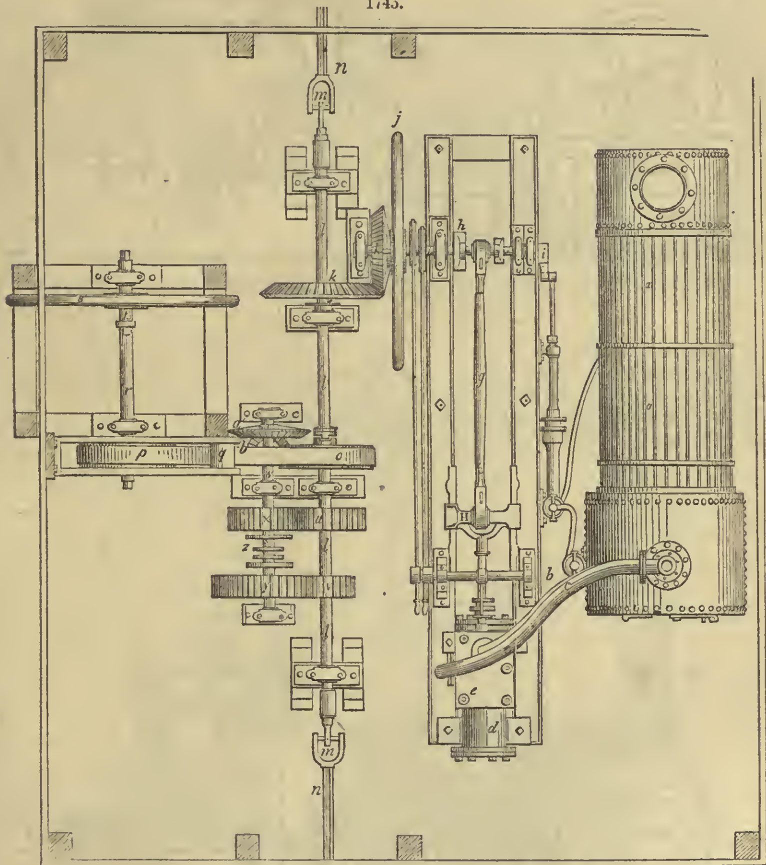
The lateral framings are furnished with two stationary spuds I I, 34 feet high and 7 inches square, provided, on one side, for 27½ feet, with a rack plate. This spud is secured into the framing at top and bottom, and is for the purpose of working the tank up and down by machinery, subsequently to be explained, and part of which is seated on the top of the tank B. Each lateral framing is also provided with a ladder N, and an upper stage for the workmen.

On each side of the centre section is an engine house, which contains the machinery for working the thrusting and pumping apparatus, and from which shafts run along the sections on each side. It should be observed that the machinery on all the sections is covered in, although it is not so represented.

The engine house contains a tubular boiler, *a*, Figs. 1739 and 1740, like a locomotive boiler, with steam pipe *b*, and exhaust pipe *c*, cylinder *d*, and valve box *e*. From the piston a cross-head carries a connecting rod *g*, working on the crank *h*, which drives the main shaft *i*, on which is the balance wheel *j*. From

the main shaft a pinion and bevel wheel k and k' carry the motion to the shaft l, which is the longitudinal driving shaft, continued, as hereafter explained, along the sections for a length of 140 feet. From this longitudinal driving shaft l, a wheel o, working by a belt on the wheel p, communicates the power to the pumping geer on the shaft r, crank t, and pump-rod t', running down to the water tanks. This geering can be thrown in and out by means of the movable pulley q, which by being raised or let fall tightens or loosens the belt on o and p. The longitudinal shaft l also works the shaft w, by which the thrusting geer is moved, and which by means of the wheels and pinions u, v, x, and y, put on or off by the clutch z, works the tank and pinion J either upwards or downwards as may be required. The shaft l is connected at each end by means of the universal joint m, and by the small circular shaft n, with the longitudinal shafting on the end sections. By this means the different sections may be placed at such distance from each other as the length of any ship may render necessary. It is to be observed, that a necessity constantly occurs for sinking one or more sections lower than the others. This is also provided for by the slip and universal joints.

1745.



The thrusting geer, Figs. 1742 and 1744, for raising and lowering the tank B, takes its motion, as mentioned, from the shaft by means of the bevel wheel, which moves the pinion at the head of the square vertical shaft. On this shaft is a movable socket, with a square hole in it, and four friction rollers, so that the vertical shaft may easily pass through it. Beneath the friction rollers is a pinion, working into the bevel wheel. This bevel wheel is on the horizontal shaft, secured into a framing on the top of the platform of the tank B. The horizontal shaft carries a worm, working into a worm wheel, the shaft of which carries a pinion J at each end, working into the spud J, which is kept in geer by a friction roller. The number of spuds is twenty-eight, four on each section, or two for each tank. On the end sections the machinery consists merely of a longitudinal shaft, the thrusting and pumping geer.

The process of taking a ship into the sectional floating dock is as follows :—The dock is sunk to any required depth by opening the gates or valves with which each water tank is furnished, and the dock necessarily sinks. The dock still being at the required depth, the ship is then introduced between the vertical side framing, rests on the keel blocks C, and when supported on the sides by the chock blocks E and side supports L, is ready for lifting.—Fig. 1737.

The valves which have previously admitted the water into the water tanks are now closed, the water

is pumped out, and the air again fills the tanks, and they rise, bringing with them the vessel to the height necessary for repairs.

The vessel is taken out of dock by a repetition of the process of admitting water into the tanks.

The patent is for the general arrangement in the construction of the side balance tanks B.

1739.

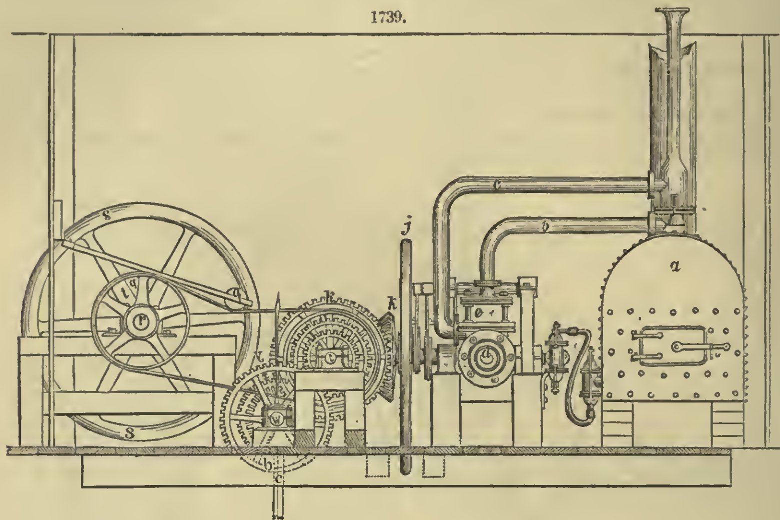


Fig. 1737.—Elevation of a section.

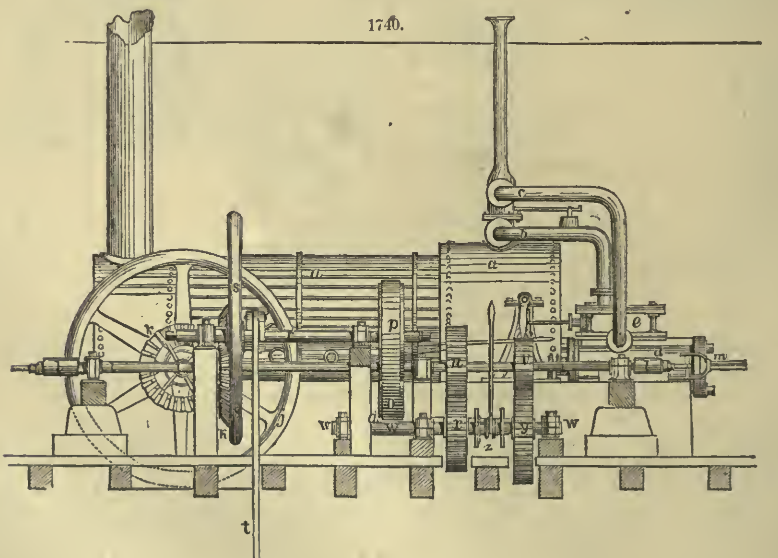
B B, the balance tanks. C, the keel block. D D, cross beams supporting the chock blocks E.

E E, the chock blocks. F F, the outside truss girders.

f f, the inside standards of the main framing to guide the balance tanks B.

*F Beam securing the standards. G G, the outside standards of ditto.

1740.



I I, the stationary spuds for working the tanks. J J, pinions working in the racks on the spuds.

K K K, outline of a vessel in the dock, supported by the side supports L L, the chock blocks E E the keel block C, and the balance tanks B B.

L L, the side supports run up and down by the blocks and tackle M M.

O O, engine houses on centre section.

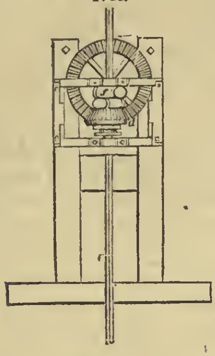
c c, vertical shaft from the main shaft in the engine houses.

g, the worm working the wheel *h*. *h*, the worm wheel working the pinion J and the spud I.

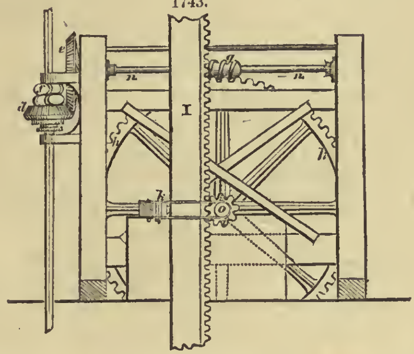
Fig. 1738.—Inner side elevation of a section.
Fig. 1745.—Plan of the engine and machinery at O on the centre section A 4 of the sectional floating dock.

a, the tubular boiler. *b*, the steam pipe. *c*, the exhaust pipe. *d*, the cylinder. *e*, the valve-box.
g, the connecting rod working on *h*. H, the cross-head. *h*, the crank on the main driving shaft *i*.
i, the main driving shaft. *j*, balance wheel.
k k', the main bevel wheel geering, transmitting the power from the main driving shaft *i* to the longitudinal driving shaft *l*.
l, longitudinal driving shaft working the thrusting geer, and communicating along the sections by *m* and *n*.
m m, universal joints connecting the shafts *l l*.
n n, small circular shafts working into the shaft *l* with a sleeve or socket and feather.

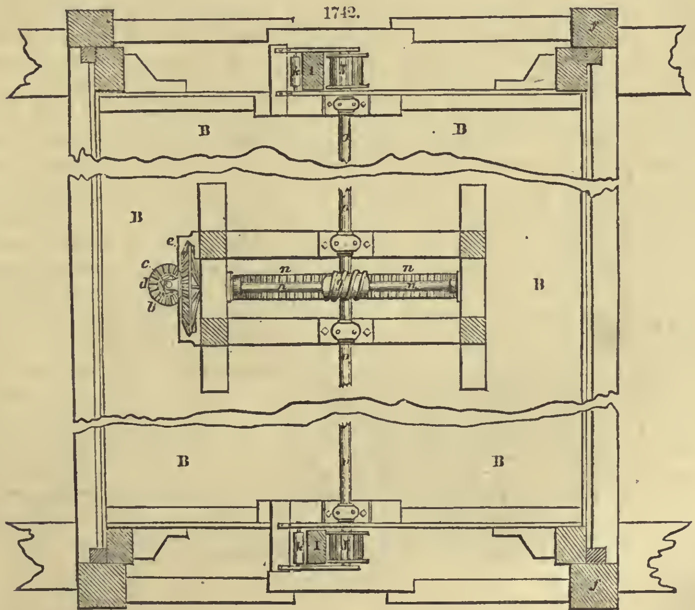
1744.



1743.



1742.



o, pulley or wheel on shaft *l* for setting in action the pumping apparatus, and connected by a belt with *p*. *p*, pulley or wheel driving the pump shaft *r*.
q, a movable pulley for tightening or loosening the belt connecting *o* and *p*.
r, a crank shaft working the pump rods *t'*. *s*, a balance wheel on the pump shaft *r*.
t, crank on the pump shaft *r*.
t', connecting rod from the crank *t* to the pumps in the balance tanks B B.
u v x y, wheels and pinions for changing the motion, making it slower or faster, and reversing the action of the spuds I. *u v*, wheel and pinion on the longitudinal shaft *l*.
x y, wheel and pinion on the thrusting shaft *w*.
w, shaft carrying the change motion wheels, and working the thrusting geer.
z, clutch for changing the motion on the shaft *w*.

$a' b'$ part of the thrusting geer taken from the shaft w. a', bevel-wheel on the shaft w.
b', pinion working on a' and moving c'. c', square vertical shaft of the thrusting geer.
Fig. 1741.—Plan of the machinery on the side sections A 1, 2, 3, 5, 6, 7 of the sectional floating dock.
Fig. 1739.—End elevation of the engine and machinery at O on the centre section A 4 of the sectional floating dock.
Fig. 1740.—Side elevation of the engine and machinery at O on the centre section A 4 of the sectional floating dock.
Fig. 1742.—Plan of balance tank B with machinery
B, the balance tank. $f f$, the inside standards of the main framing to guide the balance tank B.
c, the square vertical shaft from the shaft w.
d, small pinion working on the vertical shaft c, and on the bevel-wheel e.
e, bevel-wheel working on the worm shaft n.
f', movable socket of the shaft c, having a square hole in it, and four friction rollers on it.
n', worm shaft. g, worm working on the shaft n from the bevel e.
h, worm wheel worked by the worm g, and turning the shaft o.
o, shaft worked by h, and working the pinions J J.
J J, pinions working on the teeth of the spuds I I.
I I, upright stationary spuds for raising and lowering the balance tank B.
k, small friction roller for keeping the spud I in geer.
Fig. 1743.—Side elevation of machinery on the balance tank B.
Fig. 1744.—Enlarged front elevation of the pinion d, bevel-wheel e, and friction rollers f.

FLOOR CLOTH. This useful and ornamental manufacture was originally made of narrow canvas sewn together like sail-cloth, to which successive coats of paint were applied; but the seams proving inconvenient, a canvas was wove for the purpose, about four yards wide; it was then extended to seven yards in width, and afterwards to nine, which is the widest at present made; but the common dimensions of the oil cloths produced being 20 yards by 8, and 30 yards by 7, giving therefore entire pieces of 160 and 210 square yards without seams. These canvases are stretched upon frames, and accessible over their whole surface by stages erected for the purpose: these are the circumstances which render the large dimensions of the manufactory requisite. The canvas being duly strained, is rubbed over with pumice stone, which renders its surface smooth and even, and then brushed over with a weak solution size; when this is dry, the first coat of oil color is laid on, not with brushes, but with trowels, something in the manner of plastering; when this is dry a second coat follows it; and in this way seven coats of paint are usually applied in succession, three on the back and four on the front. When the cloth in this state, and of one color, is sufficiently dry, it is removed from its frame upon a large roller, and carried to the upper part of the building to be *printed;* that is, to receive its pattern. This was originally effected by a process of pencilling; but in the year 1780, there was introduced the great improvement of *block-printing;* by which the colors are more correctly laid on, and in greater body and variety. The printing table, which is about 30 feet long, 4 wide, and 2 feet 6 inches high, is very firmly constructed of deal timbers laid edgeways and clamped together, the surface being truly planed; the roll of painted cloth is placed underneath it, and as it is unrolled it gradually passes over the table, where it is printed, and is then drawn forward so as to hang perfectly free while drying, the height of the building being such as conveniently to admit of this, without rolling, doubling, or folding the material, which in these stages would of course injure it. The colors, which are the usual oil colors very carefully prepared, are put on in succession with wooden blocks, which are made of pear-tree, box, or holly-wood, and upon which the patterns are cut in relief; they are about eighteen inches square, and are applied in succession over the whole of the surface of the cloth lying upon the printing table. Every color is put on by a separate block, and much dexterity is required in so placing them that the patterns may correctly interlace and join each other, without in any case overlapping or interfering: to effect this, the workman is aided by guide pins, or *pitches,* as they are termed, which direct him in placing the block. The colors are first brushed or tiered upon hard cushions, from which they are transferred to the block, and thence to the cloth; and, though many are often required, it is astonishing how much effect is sometimes obtained by the judicious arrangement or mixture of two only, upon a third, which forms the ground. It will be obvious, from what has been stated, that the weight of the finished oil cloth, as compared with the naked canvas, is no unimportant criterion of its goodness; each square yard when finished weighing from three pounds and a half to four or four and a half: this distinguishes a good oil cloth from those which are vamped up and stiffened with size and other perishable materials.

Independent of the common application of oil cloths, it is not unfrequently advantageously employed as a roofing material, especially for covering verandas and other light structures. When used for this purpose, the canvas should be made of picked long flax, and thoroughly saturated with good oil paint.

FLOUR MILL. See Corn Mill.

FLY FRAME. See Speeder.

FLY-WHEEL. A large heavy wheel, used as a regulator or equalizer of motion, wherever either the power communicated or the resistance to be overcome is variable. In the one case the fly-wheel may be said to be a distributor of power. The communicated impulses act on the mass in motion, and go to preserve the momenta, without disturbing very sensibly the regularity of movement. The effect of one impulse is so absorbed or distributed in the momentum of the wheel, that its effect may be said to have hardly been diminished before the next impulse is received. In the other case, or where the fly-wheel is used to overcome a variable resistance, it may be considered a collector of power; the power having been employed to get up the speed in the fly-wheel only, is retained in the mass in movement; and the whole of the power expended, with the exception of that which has been lost through friction and resistance of the air, can be brought to bear at any instant upon the resistance to be overcome.

The applications of fly-wheels are very general;—there are few stationary engines without them

But it is usual in this country to communicate the power directly from the periphery of the fly-wheel, either by making it a geered wheel or using it as a pulley or drum, and transmitting the power through a belt or band. We know of no rules more accurate by which to calculate the dimensions of fly-wheels for steam engines, than those given by Mr. Hann. They are as follows:—

RULES FOR THE FLY-WHEEL.

For the double-acting engine, the number of revolutions, or the number of double strokes per minute, the mean radius and the horse-power being given.

To find the weight of the wheel.—Rule 1. Multiply the number of horse-power by 2275, and that product by n. Multiply the square of the mean radius by the cube of the number of revolutions per minute.

Divide the former product by the latter, and the quotient will be the weight in tons.

The value of n given by M. Morin varies with the purposes to which the engine is applied. Thus, when great regularity of movement is not required, as in saw-mills, grist-mills, the working of pumps, &c., $n = 20$ to 25. For cotton-mills spinning not less than 60, $n = 30$ to 50; for those spinning higher numbers, $n = 50$ to 60. For rolling-mills for making bar iron, with 6 to 8 sets of rollers, requiring an engine of 80 to 100 horse-power, $n = 20$; for smaller mills, of 4 to 6 sets of rollers, and engines of 60 horse-power, $n = 25$; for mills of 1 set of rollers for large bars, or 2 for small rods, and engines of 30 to 40 horse-power, $n = 80$.

To find the mean radius of the wheel.—Rule 2. Multiply the number of horse-power by n, divide the product by the area of the section of the rim, and extract the cube root of the quotient.

Divide 12·17 by the number of revolutions per minute, and multiply the quotient by the cube root before obtained. The product will be the mean radius required.

To find the area of the section of the rim.—Rule 3. Multiply 1802·9 by the number of horse-power, and that product by n. Multiply the cube of the mean radius by the cube of the number of revolutions per minute.

Divide the former product by the latter, and the quotient will be the area of the section.

For the double-acting engine, the number of single strokes per minute, the mean radius, and the horse-power being given.

To find the weight of the wheel.—Rule 4. Multiply the number of horse-power by 18200, and that product by n. Multiply the square of the mean radius by the cube of the number of revolutions per minute.

Divide the former product by the latter, and the quotient will be the weight in tons.

To find the mean radius of the wheel.—Rule 5. Multiply the number of horse-power by n, divide the product by the area of the section of the rim, and extract the cube root of the quotient.

Divide 24·34 by the number of revolutions per minute, and multiply the quotient by the cube root before obtained. The product will be the mean radius required.

To find the area of the section of the rim.—Rule 6. Multiply 14423 by the number of horse-power, and that product by n. Multiply the cube of the mean radius by the cube of the number of revolutions per minute.

Divide the former product by the latter, and the quotient will be the area of the section.

For the single-acting engine, the number of revolutions, or the number of double strokes per minute, the mean radius, and the horse-power being given.

To find the weight of the wheel.—Rule 7. Multiply the number of horse-power by 11860, and that product by n. Multiply the square of the mean radius by the cube of the number of revolutions per minute.

Divide the former product by the latter, and the quotient will be the weight in tons.

To find the mean radius of the wheel.—Rule 8. Multiply the number of horse-power by n, divide the product by the area of the section of rim, and extract the cube root of the quotient.

Divide 21·1 by the number of revolutions per minute, and multiply this quotient by the cube root before obtained. The product will be the mean radius required.

To find the area of the section of the rim.—Rule 9. Multiply 9395·8 by the number of horse-power, and that product by n. Multiply the cube of the mean radius by the cube of the number of revolutions per minute.

Divide the former product by the latter, and the quotient will be the area of the section.

For the single-acting engine, the number of single strokes per minute, the mean radius, and the horse-power being given.

To find the weight of the wheel.—Rule 10. Multiply the number of horse-power by 94880, and that product by n. Multiply the square of the mean radius by the cube of the number of revolutions per minute.

Divide the former product by the latter, and the quotient will be the weight in tons.

To find the mean radius of the wheel.—Rule 11. Multiply the number of horse-power by n, divide the product by the area of the section of the rim, and extract the cube root of the quotient.

Divide 42·2 by the number of revolutions per minute, and multiply the quotient by the cube root before obtained. The product will be the mean radius required.

To find the area of the section of the rim.—Rule 12. Multiply 75166 by the number of horse-power and that product by n. Multiply the cube of the mean radius by the cube of the number of revolutions per minute.

Divide the former product by the latter, and the quotient will be the area of the section.

Ex. 1.—A double-acting engine makes 20 single strokes per minute, the radius of the fly-wheel is 15 feet, the horse-power is 60; what must be the weight of the fly-wheel, supposing the variation to be $\frac{1}{40}$ from the mean velocity?

By rule (4,) $$\frac{18200 \times 60 \times 40}{15^2 \times 20^3} = \frac{18200 \times 60 \times 40}{225 \times 8000}.$$

$$\frac{18200 \times 60 \times 40}{225 \times 8000} = \frac{364}{15} = 24{\cdot}26.$$

Ex. 2.—Wishing to diminish the number of strokes to 17 per minute, by how much must I increase the weight of the fly-wheel to preserve the same regularity of motion?

By rule (4,) $\frac{18200 \times 50 \times 20}{100 \times 17^3} = \frac{18200 \times 50 \times 20}{100 \times 4913} = 37{\cdot}06$ tons, the weight of the wheel.

Hence, $37{\cdot}06 - 24{\cdot}26 = 12{\cdot}8$ tons, the weight by which the fly-wheel must be increased.

Ex. 3.—A double-acting engine makes 20 single strokes per minute, the horse-power is 60, the area of the section of the rim is 1·5 feet; what must be the mean radius, supposing the variation to be $\frac{1}{20}$ from the mean velocity?

By rule (5) the mean radius is $\frac{24{\cdot}34}{20} \times \sqrt[3]{\frac{60 \times 20}{1{\cdot}5}} = \frac{24{\cdot}34 \times 9{\cdot}2}{20} = 11{\cdot}2$ feet nearly.

Ex. 4.—A double-acting engine makes 20 single strokes per minute, the horse-power is 60, the mean radius of the fly-wheel is 11·2 feet; what must be the area of the section?

By rule (6) the area of the section is $\frac{14423 \times 60 \times 20}{(11{\cdot}2)^3 \times (20)^3} = 1{\cdot}5.$

In the application of the fly-wheel to the steam engine, the varying effect of the power of the steam communicated through the crank has been particularly regarded. The next consideration is to overcome variable resistances, in cases where the moving power is not steam. Here it may be remarked, estimating the force of any *prime mover* in horse-power, and taking the number of revolutions of the fly-wheel, that the rules already given for finding the dimensions of fly-wheels may be applied to mills where the resistances to be overcome are variable, as in the case of rolling-mills; in fact, the values given to n in these particular cases were intended for a mill to be driven by water, and therefore may be somewhat too small when applied to the steam engine. For the smaller variations in resistances, always experienced in the movements of machinery, no fly-wheels are necessary, when the power is constant, as in the case of water-wheels—the wheels themselves are sufficient regulators; and whenever fly-wheels are necessary, the size, weight, and velocity of the water-wheel should be taken into consideration, as it will be found to have considerable effect on the equalization of the movement.

As to the position of the fly-wheel, it should be as near as possible to the prime mover if the power is variable, and near to the resistance if this is inconstant, as the strain on the intermediate shafts would frequently be very considerable. With regard to the diameter of the wheel, it will depend considerably on position; but in some cases too small a diameter is to be guarded against. Thus the fly-wheel of an engine for a corn or flour mill, ought to be of such a diameter that the velocity of the circumference of the wheel may exceed the velocity of the circumference of the stones, to prevent, as much as possible, any tendency to back lash.

In conclusion, we give from M. Morin the rules for finding the weight of the rim of the fly-wheel when employed to overcome the resistance of forge hammers.

To find the weight in tons of the rim of the fly-wheel on the cam shaft of a forge hammer.

For the largest forge hammers, striking 70 to 80 blows per minute—

Hammers weighing 3 to 4 tons, divide 240 by the square of the mean radius.
" " 4 to 5 " " 360 " " " "

For trip hammers striking 150 to 200 blows per minute—

Hammers weighing 1000 to 1200 pounds, divide 108 by the square of the mean radius.
" " 700 to 800 " " 72 " " " "

The quotient will be the weight of the rim of the fly-wheel in tons.

FOCUS in Geometry is that point in the transverse axis of a conic section at which the double ordinate is equal to the parameter, or to a third proportional to the transverse and conjugate axis.

In optics, it is the space into which the rays of light are collected by a burning glass or mirror.

FOLDING AND MEASURING MACHINE. Formerly, for the folding and measuring of cotton cloth at the manufactories, hooks were universally used. These consist of two hooks or long needle-like points, slightly curved upwards, inserted in a wooden bar, at a distance of a yard from each other; this bar is supported on a stand at a height convenient for the operative, and at least the width of the cloth to be measured, from the floor, so that the folds may hang straight; the bar, for convenience, is often permitted to have a movement horizontally. Attaching the cloth at one corner to one of the hooks, one edge is drawn straight and hooked alternately on one and the other of the points, and in this manner the whole piece is laid in folds of one yard each.

But latterly, in the larger manufactories and bleacheries, when the quantity of cloth prepared for the market is large, the "improved cloth measuring and folding machine" has been extensively adopted this machine was patented by S. C. Durgin in 1844, and is manufactured by Gay, Silver and Co., North

Chelmsford, Mass. Introduced first at Lowell, it is now employed in all the cotton factories in that city. Since its first introduction, it has been improved in workmanship and detail; and, as an evidence of its present capability, we give the statement of W. A. Kimball, overseer of the cloth room at the Atlantic Mills, Lawrence, Mass. "One machine will fold nearly 25000 yards of cloth per day, and more cor rectly than upon hooks, and ours has run 8 months without repairs."

From the specifications at the Patent Office we take the drawings and a description, which will give an idea of the construction and working of the machine.

Fig. 1746 represents a plan or top view of the folding machine.

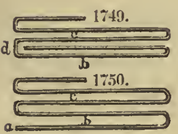
Fig. 1747 is a side elevation. Fig. 1748 is a vertical and central section.

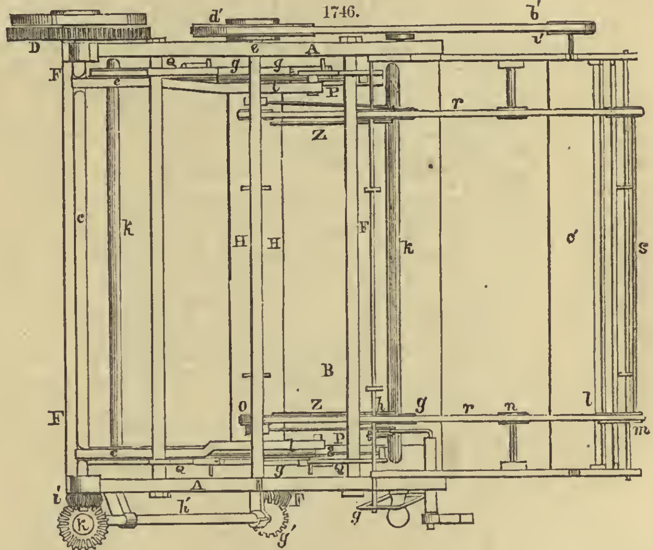
The principal operative parts of the machine are similar to those of that patented by J. Spalding, of Morristown, Vermont, in 1841. Durgin's inventions are certain improvements which render the operation of Spalding's machine more certain and expeditious.

A, Figs. 1746, 1747, and 1748, represent the main framework, which consists of two cast-iron sides or frames, rising above and secured to the ends of a horizontal platform or table B.

The main driving or crank shaft C, supported in suitable bearings arranged near the upper part of one side of the machine, is revolved by means of a spur geer D fixed upon one end of the shaft, and actuated by a toothed pinion, impelled by the driving power.

E E are connecting-rods proceeding from bell cranks F F, (upon the shaft C,) and jointed to two of the four upright sweeps Q Q Q Q, which carry the folders. These upright sweeps are suspended in a proper manner at their tops, so as to be easily and alternately vibrated backwards and forwards. The two sweeps at each end of the machine are connected together at or near the middle of each by a bar G, while the movements of the sweeps that are connected to the crank shaft cause corresponding motions of the other sweeps. The folders H H consist of two metallic plates or bars, having arms I I extending backwards and at right angles from them, which (arms) are so jointed to the lower ends of the sweeps as to permit the folders to have a vertical movement with respect to the sweeps.





The latch or retaining bars which confine the folds of the cloth down upon the platform B are seen at K K. The first improvements consist in the mechanism by which the folders are alternately lifted from and depressed upon the cloth in order to lay it in successive folds upon the platform. At or near the centre of the inner side of each bar G a pulley L is arranged upon a pin M, projecting from the bar, the said pulley turning upon the said pin. Upon each of these pulleys a chain or band N passes, having its ends attached to collars O O, of two bent rods P P, each of which is jointed at one end to one of the sweeps Q Q, (or moves upon a pin inserted horizontally therein,) in the position, as seen in Fig. 1748. and passes and moves freely at its other end through a vertical stud R, rising upwards from the arm of the folder. Each of the collars O O should be movable upon its rod, and so arranged as to be confixed upon any desirable part of the rod by a set screw, so by moving the collars into suitable positions on their respective rods the folders may be balanced when in the centre of the machine. Each pulley has one end of a cam lever S attached to its side, and near its periphery, by means of a pin or stud *a*, upon which the lever works. The cam lever has a semicircular slot *b* and a straight slot *c* formed on its opposite end, as seen in Fig. 1748, and is connected to one of the sweeps Q by pins *d e*, projecting from the inner side of the sweep, and passing through the grooves *b c*. The two cam levers extend from their respective pulleys in opposite directions to each other, being connected to the sweeps as in Fig. 1746.

Now when the sweeps are moved to and fro by means of the crank shaft, the slots *b* and *c* in each of the levers will permit the levers to accommodate themselves to the motion of the sweeps, and to turn their pulleys L L around a short distance upon their axis, and thus gradually elevate one of the folders

above the platform, and the latch or retaining bar towards which the sweeps are moved, and at the same time depress the other folder towards the platform.

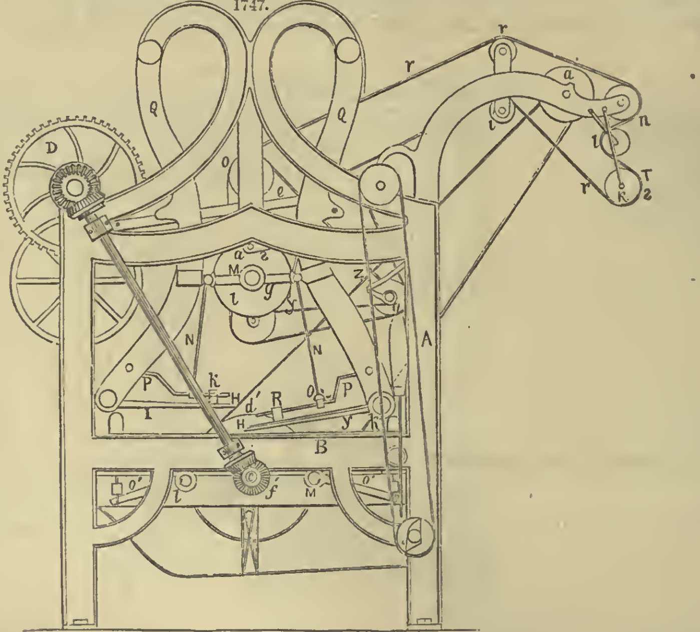
During the elevation of either of the folders above the platform, the rods P P of the folder pass or move longitudinally through the studs R R, and so as to cause the collars O O of the rods to approach towards the studs. So when either of the folders is depressed towards the platform, the rods P P of it move in the opposite direction through the studs R R of it, and carry the collars away from the studs. By this peculiar operation the balance of the folders is overcome, and that folder which is in immediate action upon the cloth, or which is pressing the same towards one of the retaining bars or latches, is depressed upon the cloth, and bears thereon with a slight force, and at the same time raises the other folder above the cloth and the retaining bar, towards which the depressed folder is proceeding.

The next improvement consists in the mechanism by which the cloth is introduced into the machine, and the overlap of the first fold produced. It is customary, in folding piece goods by hand, to turn the end of the piece between the folds *b* and *c*, as seen at *a*, in Fig. 1749. By the ordinary folding machine, the same has been arranged in the order as seen in Fig. 1750. The placing the ends between the folds *b* and *c*, as in Fig. 1749, is what is termed "the overlap of the first folds."

A small horizontal shaft *f*, supported so as to revolve in suitable bearings, extends across the machine from one end of the frame to the other, in the position seen in Figs. 1746 and 1748. This shaft is put in revolution by a pulley *z*, arranged upon one end, which (pulley) is driven by a band proceeding from the driving power, and the power which operates the shaft *f* should be so applied that it can be put in action and thrown out thereof at pleasure.

There are two pulleys placed on the shaft *f* near its ends and at equal distances on each side of the centre of the shaft, one of these pulleys being represented in Fig. 1748, at *h*.

1747.

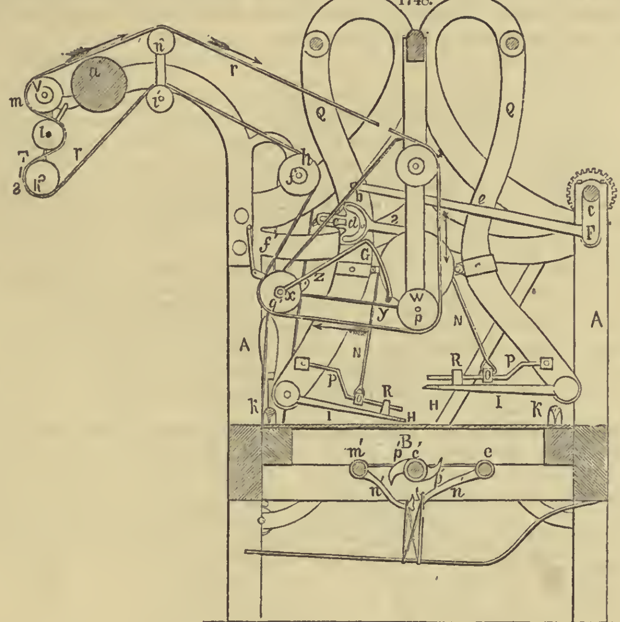


A series *i k l m n o p q* of pulleys, arranged in the positions with respect to each other, and the pulley *i*, as seen in Fig. 1748, and in the same vertical plane with one of the pulleys *h*, is disposed at each end of the machine, they being supported by suitable shafts extending across or projecting from the framework. Over each series of pulleys a band *r* passes, as seen in Figs. 1746 and 1748, and between the bands *r r* a metallic or wooden bar *s* extends, having its two ends attached to the band, as represented in Fig. 1746.

Small hooks or pins *t t* and *c* are inserted in the upper edge of the bar, upon which (hooks) the end of the piece of cloth to be folded is hooked, so as to confine the said end to the bar. This being accomplished, the shaft *f* is to be put in revolution so as to cause the bands *r r* and bar *s* to move in the direction denoted by the arrows in Fig. 1748, and the cloth into the machine until the bar *s* arrives at or near the point *t*, when the revolution of the shaft *f* is to be stopped. The cloth thus drawn in will pass over the horizontal shafts *u v*, and under the horizontal shaft *w x*. In its passage from the shaft *w* to the shaft *x* it passes beneath a horizontal rod or bar *y*, which is supported at its ends by bent arms *z z*, extending from the horizontal shaft *x*. Therefore, on turning the shaft *x* in its bearings, it causes the bar *y* to descend in a curved direction towards one of the retaining bars *k*, and to press or carry the cloth down with it, and to deposit it in a lap underneath the retaining bar. On unhooking the end of the piece of cloth from the points of the bar *s* and putting the folders in operation, the end of the cloth will be smoothed down upon the platform and then the overlap of the first fold will be produced. In its passage into the machine the piece of cloth passes over a feeding roller *a'*, which is arranged in

the position denoted in the drawings, and moved by a belt or band b' passing around a small pulley c', (fixed on the axis or shaft of the feeding roller,) and a large pulley d' fixed upon one end of a horizontal shaft e', Figs. 1746, 1747, and 1748, which extends centrally under the platform from one end of the machine to the other, and has a bevelled pinion f fixed upon its opposite end, which (pinion) works into another bevelled geer wheel g' fitted upon the lower end of an inclined shaft h'. A bevelled geer i, fixed on the end of the crank shaft, imparts motion to the inclined shaft, by engaging with another bevelled geer H, fixed on the upper end of the shaft h. The central shaft e has two other shafts l' and m' arranged horizontally on opposite sides of it, as seen in Fig. 1748, and extending from one end of the framework to the other. Each of the shafts $l\,m$ has an arm n, (projecting from the centre in a direction towards the shaft e,) and two arms projecting in opposite directions from its end respectively, one of the latter arms being seen at O, Fig. 1748. Each of the retaining bars rests upon two of the arms O′, by means of suitable guides of the retaining bar projecting vertically through the platform and resting upon the arms O O. The central arms n of the shafts $l'\,m'$ are alternately depressed by cams or wipers $p\,p$, fixed upon the central shaft; the depression of the said arms elevating the retaining bars. The surface of the roller a should move a very little faster than the cloth does, as it (the cloth) is drawn by the folders over the guide shafts $w\,v$ in order that the portion of the cloth which is between the feeding roller a and the shaft u may hang loosely between the two rollers, and the feeding roller do all the work of drawing the cloth towards itself, and thus freeing the folders from the strain in consequence thereof; thereby enabling them to perform their operations with certainty and ease.

1748.



Having thus described the machine, Durgin claims the mechanism by which the folders are elevated and depressed, the same consisting of the pulley L, cam lever S, bent rods P P, chain or band N, and parts as before described, as combined with each other and applied to the folders and sweeps. Also the mechanism by which the cloth is introduced into the machine, and the "overlap of the first fold" produced, the same consisting of the endless band $r\,r$, (with the pulleys and shafts arranged substantially as described,) and cross bar S, or machinery of similar character in combination with the depressing bar y.

Also the peculiar method of feeding the cloth into the machine so as to present it to the action of the folders as required by them, and with little or no strain upon them, viz. by supporting the cloth on one or more horizontal rods or shafts $u\,v$, (placed above the folders,) in combination with giving to the surface of the feed rollers a motion sufficiently increased beyond that of the folders, to cause that part of the cloth which is between the supporting rod or rods and the feed roller to be loose or hang down in proper quantity, to readily yield to the irregular motion of the folders over the platform, caused by the cranks of the shaft which operates the sweeps of the said folders.

FORCE. Force is the cause of motion or change of motion in material bodies. Every change of motion, viz. every change in the velocity of a body must be regarded as the effect of a force. On the other hand, rest, or the invariability of the state of motion of a body, must not be attributed to the absence of forces, for opposite forces destroy each other and produce no effect. The gravity with which a body falls to the ground still acts, though the body rests; but this action is counteracted by the solidity of the material upon which it reposes.

Forces that are balanced, so as to produce *rest*, are called *statical* forces or *pressures*, to distinguish them from *moving*, *deflecting*, *accelerating*, or *retarding* forces; *i. e.* such as are producing *motion*, or a

change in the direction or velocity of motion. This distinction is wholly artificial, for the same force may act in any of these modes; it may sometimes be a statical, and sometimes an accelerating force; but it is convenient to confine our attention in the first instance to forces in a statical point of view.

Statical forces can, of course, be compared only with each other, but the ratio between any two quantities may be represented by the ratio between two other quantities, however different in kind from the first two: thus, two pressures may have the same ratio as two lines, or two surfaces, or two bulks, or two times, or two numbers. Now, when we represent magnitudes of any kind by numbers, we in fact compare them with some fixed or standard magnitude of the same kind, which we represent by the number 1: thus, the units commonly used for comparing *lengths*, are *inches*, *feet*, *miles*, &c.; and so also the units of *pressure* are *ounces*, *pounds*, *tons*, &c.

In strictness, however, these terms do not properly express units of *pressure*, but of *mass*, (or quantity of matter;) and they are used as standards of pressure simply because the earth's attraction on a given quantity of matter is always the same *at the same place*, and differs but slightly in different places. But the same mass, in a different situation, (as regards latitude, or level,) would gravitate with a rather greater or less pressure. *Mass* must not be confounded with *weight*, because the same names are applied to the units of both; for, in fact, the units of pressure are quite distinct from, though founded on, those of mass; just as the latter are derived from those of *length*, and all from that of *time;* the connection being as follows:—

1. A *pound pressure* means, that amount of pressure which is exerted towards the earth, in the latitude of London and at the level of the sea, by the quantity of matter called a pound.
2. A *pound of matter* means a quantity equal to that quantity of pure water which, at the temperature of 62° Fahrenheit, would occupy 27·727 cubic inches.
3. A *cubic inch* is that cube whose side taken 39·1393 times would measure the effective length of a London seconds pendulum.
4. A *seconds* pendulum is that which, by the unassisted and unopposed effect of its own gravity, would make 86,400 vibrations in an artificial solar day, or 86163·09 in a natural sidereal day.

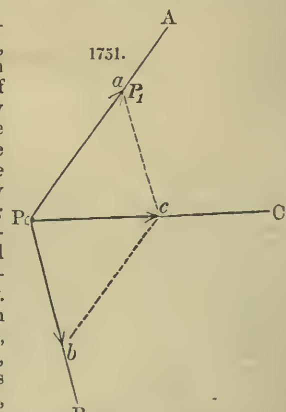
Forces may also (like any other magnitudes) be represented by lines of definite lengths. A unit of length being taken to represent the unit of pressure, the length of the line represents the magnitude of the force; but the line has this great advantage over a number,—its direction represents the direction of the force; and its commencement or extremity, the point at which the force acts, or its point of application: thus, by a line, the force is completely defined in all its three elements; while a number can only represent *one* of them, viz. its *magnitude.*

In this way forces can be brought under the domain of mathematical science, geometry serving to investigate their various relations by means of lines, arithmetic by means of numbers, and algebra and trigonometry by the properties common to directions and magnitudes of all kinds.

If two forces be in equilibrium at a point, they must be equal in magnitude, and opposite in direction. But whatever number of forces may act upon a point, and whatever their directions, they can only impart one single motion in one certain direction. We may, therefore, incorporate all these single forces into one force, or *resultant*, capable of producing the same mechanical effect as the forces themselves, which are called the *components.*

When any number of forces act at a point in the same straight line, and in the same direction, the resultant is equal to their sum; if the forces act in opposite directions, the resultant is equal to their difference.

1751.

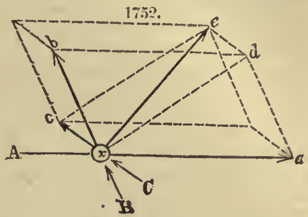


When two forces act upon a point in different directions, the resultant is found more easily by the geometrical method. It is obvious, in the first place, that the line representing the resultant must lie in the same plane which contains the directions of the two forces; for if not, on which side of the plane should it lie? There is evidently nothing to determine it to one side more than the other. For the same reason, when the forces are *equal*, the resultant must bisect the angle between their directions, for it cannot be nearer one than the other. Moreover, in all cases, whether equal or not, the nearer they coincide in direction, the greater will be the resultant, and *vice versa;* since their exact coincidence makes it equal their *sum*, while their exact opposition makes it equal their *difference.* But it is doubtful whether elementary mathematics will carry us further than this without the aid of experiment, which teaches us the following beautiful law.

Let the point P, Fig. 1751, be acted on by two forces, pressing in the directions P A and P B. From the point P, upon the line P A, measure off any length P *a*; and from the point P, upon the line P B, take a length P *b* bearing the same ratio to P *a* that the force B bears to the force A. The easiest way to do this is to make the lines P *a*, P *b*, contain respectively as many units of length (inches or feet, for example) as the forces A B contain units of force, (ounces or pounds, for example.) Through *a* draw a line parallel to P B, and through *b* draw a line parallel to P A, these lines will meet at some point *c*. We thus get a parallelogram P *a c b*; and the line P *c*, called its *diagonal*, will represent a single force acting in the direction P C, and consisting of as many units of force as the line P *c* contains units of length; and this force will produce upon the point P the same effect as the two forces P A and P B produce acting together.

This method of finding an equivalent, or the resultant of two forces, is called the *parallelogram of forces*, and is thus concisely expressed:—"If two forces be represented, in magnitude and direction, by the sides of a parallelogram, an equivalent force will be represented, in magnitude and direction, by its diagonal." The two forces are called, the *components* of the resultant.

Any number of forces, acting at one point, can be compounded by the same rule. For instance, let the body x, Fig. 1752, be pressed at once by the three forces whose directions are expressed by the arrows A B C, and their magnitudes by the lengths $x\,a$, $x\,b$, $x\,c$. We may first compound any two of them, (such as A and B,) by completing the parallelogram $x\,a\,d\,b$, by which we find that the direction of their resultant is $x\,d$, and that its magnitude is to their magnitudes as the length $x\,d$ is to the lengths $x\,a$, $x\,b$. We may then compound this resultant with the remaining force $x\,c$, by completing the parallelogram $x\,d\,c\,e$, the diagonal of which, viz. $x\,e$, will represent both the magnitude and direction of the general resultant of all three forces; so that a force of the magnitude expressed by this length $x\,e$, and acting in the direction $e\,x$, would balance those three forces. Of course the resultant of any greater number of pressures might have been found in the same way, by combining two at a time.



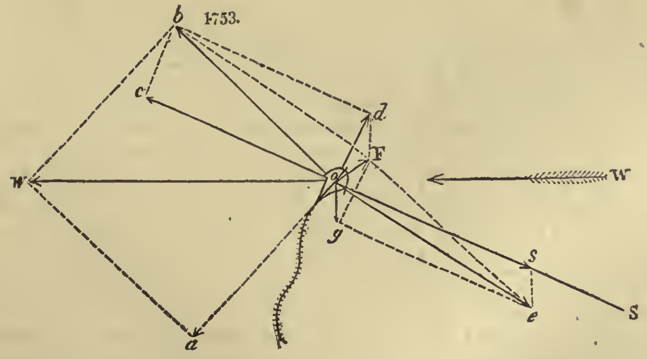
1752.

In this problem it matters not whether the directions of the forces lie all in the same plane or in different planes. In the latter case, the three lines $x\,a$, $x\,b$, $x\,c$ would form the three edges that meet at one solid angle of a *parallelopiped;* and by completing this solid figure, as shown by the outer dotted lines of Fig. 1752, its diagonal $x\,e$ will represent the resultant. Hence, whether we regard the lines of this figure as they really lie flat on the paper, or as the projection or picture of a solid parallelopiped, the law is equally true. The same process is of course capable of being extended to any number of forces in different planes.

It would scarcely be possible to arrive at some of the simplest results of its application to every branch of physics, if recourse were not constantly had to the inverse problem of the *resolution* of forces. It is constantly necessary to consider a force as capable of being resolved into two or three distinct forces, having different directions; for it is evident that we may substitute for any given force, any number of other forces, having any given directions, (not opposite to each other;) for we may make the line $x\,e$ the diagonal of any number of parallelograms, or parallelopipeds, having their sides running in any proposed directions. When their directions are decided on, their lengths will be discoverable; and thus we shall know both the directions and magnitudes of the forces into which, for convenience sake, the whole, or *resultant* force, has been resolved.

Examples of the composition of forces are of constant occurrence, as in the exertions of our limbs, the action of the various tools and implements which we employ, and the external actions in which we participate. It is frequently of importance to consider whether the component forces are employed so as to produce the best resultant; that is, one acting in a direction most available for the object intended to be accomplished, and with as small an expenditure of force as possible.

As a familiar illustration of the composition of forces, take the flying of a boy's kite. To counteract (permanently) the force of gravity which would bring it to the ground, two other forces at least are required—viz. the wind, and the resistance of the string or of the point where it is fixed or held. The wind alone would keep it suspended, but only for a time—viz. until the kite had either turned its edge to the wind, (so as to be pressed no more on the under than on the upper side,) or else had become vertical, so as to be pressed only horizontally and not upwards. If the kite had no tail, the former effect would rapidly ensue, and with a tail the latter would be equally certain. It is necessary, therefore, that the kite be *inclined,* and this is effected by the string being attached at such a point as to leave more surface (and therefore, a greater pressure of wind) below the point of attachment than above it. This excess of pressure on the lower half drives it to leeward, but only to a certain extent, where it is counterbalanced by the weight of the tail. The horizontal force of the wind W, Fig. 1753, the intensity of which is represented by the line $o\,w$, must be resolved into two portions, one parallel, and the other perpendicular to the surface. The former portion $o\,a$ has no effect; the kite is pressed only by the other portion, in the direction $o\,b$, in which direction it would move, if it maintained its inclined position, and were subject to no other force than the wind. But there are two other forces, the string and gravity. Supposing the string to pull in the direction o S, we shall find the intensity of this force by resolving the whole effect of the wind on the kite represented by $o\,b$, into two portions, $o\,d$ perpendicular to the string, (and therefore not resisted by it,) and $o\,c$, which must be balanced by an equal and opposite force in the string, which will accordingly be represented by $o\,s$. The action of the string and



1753.

wind alone would therefore be to urge the kite in the diagonal *o d* of the parallelogram *o b d s*; but with this we must further compound the force of gravity, which (the kite being very light) we will represent by the short line *o g*, and this, compounded with *o d*, gives the resultant *o* F, in which direction the kite will rise when subject to all three forces, in the degrees here supposed. If the wind suddenly cease, the resultant of the string and gravity is found by compounding *o s* with *o g*, which gives *o e* as the direction in which the kite would then be pulled; and this compounded with the *effective* portion of the wind's force, viz. *o b*, will give *o* F as before. In this direction, then, the kite will, under these circumstances, rise till it has attained a position where the three forces *o b*, *o s*, and *o g*, are in equilibrium, *i. e.* where each is equal and opposite to the resultant of the other two, in which case we should on our construction find *o* F = O, or the point F would coincide with *o*.

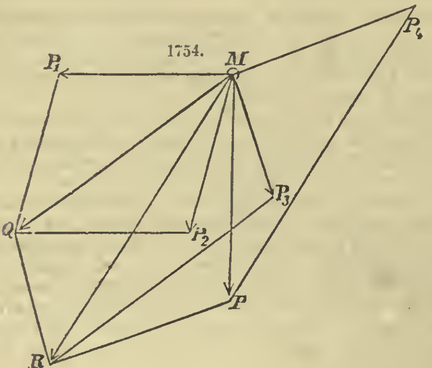
In order to raise the kite to its greatest altitude, the most advantageous angle for the kite to form with the horizon is 54° 44′; which is the same as the rudder of a ship should make with the keel, in order that the vessel may be turned with the greatest facility, supposing the current to have a direction parallel with the keel; and the same that the sails of a windmill, and the vanes of a smoke-jack or of a screw-propeller, should make with the plane of their rotation.

Forces in a plane.—In order to find the mean force P for a system of forces $P_1 P_2 P_3$, &c.: by the repeated application of the parallelogram of forces, we may resolve them two and two and so on, till but a single force remains. The forces P_1 and P_2, for example, give from the parallelogram $M P_1 Q P_2$, the mean force M Q = Q; if this be joined to P_3, we have from the parallelogram $M Q R P_3$, M R = R; and this last again forms a parallelogram with P_4 and gives the force M P = P the last, and the resultant of the four forces $P_1 P_2 P_3 P_4$.

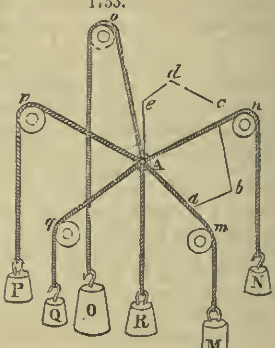
It is not necessary, in this way of composing forces, to complete the parallelogram, and draw its diagonal. We may form a polygon $M P_1 Q R P$, whose sides $M P_1$, $P_1 Q$, Q R, R P, are parallel and equal to the given components $P_1 P_2 P_3 P_4$, the last side M P completing the polygon will be the mean force sought, or rather its measure.

This simple and elegant theorem is called *the Polygon of Forces.* By this, any number of statical forces are represented in direction and magnitude by the sides of a polygon, taken in order; and they will, when applied to one point, produce equilibrium.

1754.



1755.



To make this theorem clearer, attach a number of pulleys to a vertical plane, such as an upright board, and carrying over them the lines which represent the forces, and attach weights to their extremities, as in Fig. 1755. Then take any part A *a* on the string A *m*, and from *a* on the board, draw a line parallel to the string A *n*, and take a part *a b* upon that parallel, such that A *a* is to *a b*, as M is to N. Again, through *b* draw a parallel to the string A *o*, and on that parallel take a part *b c* such that *a b* is to *b c* as N is to O. In like manner, draw *c d* parallel to A *p*, and such that *b c* : *c d* : : O : P; and draw *d e* parallel with A *q*, and bearing the same relation to the other lines that Q bears to the other weights. Finally, join the points *e* and A by a right line. A single force R, acting in the direction of the line *e* A, and having the same ratio to each of the other forces as the line *e* A has to the side of the polygon, which is parallel to that other force, will produce a pressure on the fixed point A equivalent and opposite to the combined actions of the forces M N O P Q. This may be proved by attaching any weights at random to the various strings, and (when they have settled in equilibrium) making the construction above described, beginning with any side of the polygon, and making all its sides, except one, parallel with their respective strings, and with lengths proportional to their respective weights. The remaining side will then be found to lie always in a straight line with the remaining string, and to have the exact length proportioned to the remaining weight.

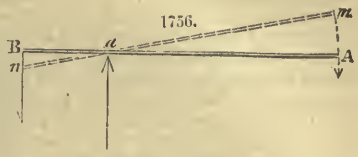
Parallel forces.—It is evident that forces may be made to act side by side with quite as much effect as in the same straight line. Two horses drawing a cart may of course be placed side by side, or one before the other, and the effect will be the same. Hence, the resultant of two parallel forces, acting in the same direction, is equal to their sum; it has the same direction with them, and when they are *equal*, is applied at a point midway between their points of application. But when they act in contrary directions, they have *no* simple resultant, for they tend to produce *rotation*, and this tendency cannot be counterbalanced by any single force.

When two parallel but unequal forces are supported or balanced by a third, it must be equal to their

sum, it must act in the contrary direction, and must be applied at a point nearer the greater force than the less, its distances from them being inversely as their intensities.

Thus, in Fig. 1756, when the three forces at B A and a are in equilibrium, B : A : : the distance A a : the distance B a.

1756.



When one point of a rigid body is supposed to be immovably fixed, the effect of any forces applied to that body can only be to *turn* it *round* the fixed point, as a *centre* of motion; and when two points are fixed, the motion can only be round the line joining them, which thus becomes an *axis*. Now, as has been said above, two forces which tend to turn the body in contrary directions will be in equilibrium if their intensities are inversely as their distances from the centre or axis. But in every inverse proportion, the product of the first and second terms is equal to the product of the third and fourth; or the product of the first and third = that of the second and fourth. Thus, instead of saying that the forces A and B are inversely as the distances a A and a B, we may express the same thing by saying that the product of the force A × the distance a A = the product of the force B × the distance a B. Thus, if a straight bar be balanced, as in Fig. 1756, and, at the distance of *one foot* from its fulcrum, or point of support, a weight of 12 pounds be suspended, it will be found that this weight will be balanced by a weight of 6 pounds, distant 2 feet on the other side of the fulcrum; or by a weight of 4 pounds at the distance of 3 feet; or by a weight of 3 pounds at the distance of 4 feet. Now by multiplying these weights by the number of units (feet) representing the distances from the centre, we get in each case 12; thus 6 pounds at 2 feet = 12 pounds placed at 1 foot, or $6 \times 2 = 12 \times 1$. In like manner, 4 pounds at 3 feet, or $4 \times 3 = 12$; and 3 pounds at 4 feet, or $3 \times 4 = 12$.

These products are called the *moments* of the force.

It is evident, also, that by increasing the number of forces on each side of the axis, the body will be in equilibrium, provided the sum of the moments of those forces which tend to turn it round in one direction, be equal to the sum of the moments of the forces which tend to turn it round in the other direction.

As this principle may be considered as the basis of mechanical science, it is desirable to illustrate it by another method. If two weights in equilibrium, as in Fig. 1756, at the extremities A and B of a bar supported on an axis a, passing through its centre of gravity, be made to oscillate gently through a small space, it is evident that the spaces moved through by the two ends of the bar will be directly as their distances from the axis; for, the angles A a m and B a n being equal, the arcs A m and B n, are as their radii a A and a B. For instance, if the weight B be 12 pounds, suspended at 3 inches from a, its moment may be expressed by the number 36; and it will be balanced by a weight of 6 pounds, 6 inches from a, because its moment is also 36. Now if these two weights be made to oscillate through a small space, such as B m for the weight which descends, and A n for the weight which ascends, the latter space will be only half the former, because it bears the same ratio to a B (or 3 inches) that A m bears to a A, (or 6 inches.)

Hence, if B n be one inch, A m will be two inches, and the products of these two quantities with their respective weights will be equal to each other; that is, the effect of 12 pounds moving through 1 inch, or of 6 pounds moving through 2 inches of space, is the same. And though we are not now concerned with motions, but with *pressures*, the same principle applies to them. Any two pressures, however unequal, (a pressure of 1 pound and one of 1000 pounds, for instance,) will balance each other, if they are so applied that the motion of the first through 1000 inches would be necessarily accompanied by a motion of the second through one inch, and *vice versa.*

This principle is known under the name of the principle of *virtual velocities*, and is that which regulates the action and constitutes the efficacy of every machine in which power is employed to overcome weight or resistance. In the composition of machines it is usual to speak of *six mechanical powers;* namely, the *lever*, the *wheel and axle*, the *pulley*, the *inclined plane*, the *wedge*, and the *screw;* although in reality these contrivances are but applications of the principle of virtual velocities, whereby a small force acting through a large space, is converted into a great force acting through a small space. But in this there is no gain of power, neither is there any loss; the advantage is in its application. Every pressure acting with a certain velocity, or through a certain space, is convertible into greater pressure, acting with a less velocity, or through a smaller space; but the quantity of mechanical force is not altered by the transformation, and all that the mechanical powers can accomplish is to effect this transformation.

Thus far we have regarded force simply as that which is necessary to oppose or balance force. We are now to consider it as *the cause of change of motion. Force*, in the sense in which we have already used it, is not required for the maintenance of motion, but only for its *change*—i. e. for effecting, 1st, a change of *state* from rest to motion, or from motion to rest; 2d, a change in the *velocity* of motion, either by accelerating or retarding it; or 3d, a change in its *direction*, by deflecting it upwards, downwards, to the right, or to the left. The *inertia of matter* is only another mode of impressing this idea. And since matter is inert, that is, has no tendency either to rest or motion, a body impressed with a motion must persist in that motion, in a straight line and with uniform velocity, for ever, unless some new force act upon it, either to change its state, its direction, or its velocity; for it cannot of itself change either its state of rest or its state of motion, its velocity, or its direction. This is inferred from experiments and observations on all the motions presented to our notice either in the heavens or on the earth, and is known to be true, because any other law which can be substituted for it will be incompatible with some or all of those motions.

We are therefore to regard as being in equilibrium, not only such bodies as are at rest, but also such as are performing uniform rectilinear motion; for it is only while their velocity or direction is changing that the forces acting on them can produce a resultant pressure; and as long as this pressure remains

unbalanced, the motion will continue changing in velocity, or direction, or both; whenever it becomes straight and uniform, the resultant of all the forces acting on the body $= 0$. Thus, when a train or a steamboat has started, its velocity continues for a certain time to increase, because the forces that urge it forward exceed the friction in one case, or the resistance of the water against the bows of the boat in the other; but these opposing forces are dependent on the velocity and increase, because it increases so that they presently become equal to the forward force imparted by the engines, and then the motion becomes uniform, and the body, though moving at its full speed, is as completely in equilibrium as when it was at rest. Thus the motive power is required, not to maintain the *motion*, but to maintain *equilibrium* with the opposing friction or resistance. The motion is maintained because the body has been set in motion, and being inert, has no tendency of itself to alter that state; and also because any alteration of velocity would, by increasing or diminishing the resistance, while the steam power remains unaltered, leave a portion of the former or of the latter unbalanced, and this unbalanced force, acting against or with the direction of the motion, would retard or accelerate it till the former velocity was re-established. Thus the equilibrium is stable, or tends, when disturbed, to restore itself.

The dynamical effect of force being a change in motion, a continued force or *pressure* must produce a continuous change, whether in velocity or direction. The simpler effect of a sudden change of velocity, or an angular deflection, can only be produced by an *impact*, or instantaneous exertion of force.

The greater part of the forces which impart motion to a body act directly upon only a few of its molecules: thus, when a billiard ball is struck with the cue, we touch only a small portion of its surface. As all the parts of a body are set in motion by an impulse communicated to a few only of its molecules, it is clear that there must be a diffusion of motion from the parts acted on over all the other parts of the body before it can begin to move. When this is not the case, the part struck is compressed, or it is chipped off, and performs its journey alone, leaving the mass behind; but when the force has *time* to be propagated through all the particles, the body is then impressed with a motion common to all its particles.

When a force has acted upon a body, and the motion has diffused itself over all the molecules, so as to impress them with a common velocity, the force has done its work; it has produced its effect, and may be said to have passed from the moving power, or source of motion, into the thing moved. Thus a stone projected by the hand, describes a certain path in space in obedience to the force which has acted upon it once for all, and then ceased, leaving the force thus impressed to do its work. Now, if the stone in its progress met with no other form of matter at rest or in motion—if, in short, no other force acted upon it, it would continue to move with the same velocity and in the same direction forever.

But the same force does not produce the same effects on different bodies. The charge of powder capable of projecting a small shot, for example, may scarcely produce the slightest motion in a cannon ball. And it is an established principle in mechanics, that when the same force acts upon different bodies free to move, their velocities are in the inverse ratio of their masses, or of the quantity of matter of which they are composed. Thus the same charge of gunpowder which would project leaden balls whose volumes or masses were as 1, 2, 3, 4, &c., would impart velocities to them as the numbers 1 $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c.; hence it will be seen that the mass multiplied into the velocity gives in each case the same number; in the first case, $1 \times 1 = 1$; in the second, $2 \times \frac{1}{2} = 1$, and so on. When there is no friction, the smallest impact is sufficient to impart motion to the largest mass; but only, of course, a very slow motion. This product of the mass of a moving body by its velocity, is called the *momentum*, or *moving force*, or *quantity of motion*. The same impact always gives the same quantity of motion, whatever may be the body which it impels; so that the true measure and characteristic of an instantaneous force or impact is the quantity of motion it is capable of imparting. Thus we may describe an impact by saying that it is equal to 50 pounds moved 1 foot per second, or 1 pound moved 50 feet per second, or 2 pounds moved 25 feet per second, &c., &c., all meaning the same thing.

In ordinary language, the *force* of any moving body means its momentum, or the impact required to stop it, or to impart the same quantity of motion to a body previously at rest. But the useful effect is in most cases proportional, not to the *momentum*, but to the *vis viva*. Hence—1. When equal masses are in motion, their forces are proportional to their velocities. 2. When the velocities are equal, their forces are proportional to their masses, or quantities of matter. 3. When neither the masses nor velocities are equal, the forces are in the proportion of both taken jointly, that is, the proportion of their products.

Thus the force of a moving body, or the work which it will perform *in a given time*, (that is, its *momentum*,) varies as its *velocity* multiplied by its weight; but its whole accumulated force, or the total amount of work which it will perform, *no matter in what time*, in being brought to a *state of rest*, (that is, half its *vis viva*,) varies as the *square of its velocity* multiplied by its weight. In order to illustrate this, let us suppose a railway train of a certain weight in motion upon a perfectly level and straight railway, and let us assume that the resistances opposed to its motion are the same, whatever may be its velocity, the practical incorrectness of this assumption not affecting our present object. Imagine the velocity of the train to be fifteen miles per hour, and let it be desired to bring it to a state of rest at a station which it is approaching; suppose that the engine driver, judging from experience, shuts off the steam at a distance of a mile from the station, and that the resistance experienced by the train in moving over this mile is just sufficient to bring it to rest at the station, the time occupied in passing over the mile being six minutes. Now if we again suppose the same train to be moving with a velocity of thirty miles per hour, and it be desired to stop at the station, then, the resistance being the same as before, it will in this case be necessary to shut off the steam at a distance of four miles from the station, in order that it may be brought to a state of rest there, and the time which the train will occupy in passing over these four miles will be twelve minutes. Again, let two bodies, both of the same weight, be projected upwards, one with double the velocity of the other, and suppose the resistance of the air removed, and only the force of gravitation, perfectly uniform in its action, to be opposed to the motion

of the bodies; then will the body projected with twice the velocity rise to four times the height, against the same resistance, before being brought to a state of rest, but it will occupy, in doing so, twice the time similarly occupied by the slower body.

When two masses moving in the same direction impinge one upon the other, and after impact move together, their common velocity may be determined by multiplying the numbers expressing the masses by the numbers which express the velocities; the sum of the two products thus obtained, divided by the sum of the numbers expressing the masses, will give a quotient expressing the required velocity.

For example, if a musket-ball weigh one-twentieth of a pound, and its velocity on being fired be 1300 feet per second, if it strike a cannon-ball of 48 pounds, suspended by a string, it will set it in motion; and the common velocity of the two is to that of the bullet as $\frac{1}{20}$ is to $48 + \frac{1}{20}$, or as 1 is to 961; the common velocity of the two is, therefore, $\frac{1300}{961}$, or about $1\frac{1}{3}$ feet per second.

When a musket-ball strikes against a large stone, or is fired at a mountain, it communicates both to the stone and the mountain a certain velocity, small indeed, and not measurable unless we knew the mass of the mountain in addition to other particulars. In fact, motion can only be destroyed by motion; resistances and friction disperse it, but do not destroy it.

The resistance which a moving body meets with in the air, or in the water, is only an effect of the transference of motion. A body moving in water must constantly displace a portion of the fluid equal to its own bulk, and the amount of motion thus communicated to the water is so much lost by the moving body. It is generally admitted in such cases that the resistance is in proportion to the square of the velocity of the moving body. When the velocity is doubled, the loss of motion by resistance is quadrupled, because not only is there twice as much fluid to be moved in an equal time, but it has to be moved with twice the velocity. So also when the velocity is trebled, the moving body meets three times the number of particles, to which it communicates three times the velocity, thereby occasioning nine times the loss. The resistance to a body moving in water is, therefore, about 800 times greater than if it were moving with the same velocity in air, for it has to move 800 times as much matter in the same time. But if the motion in air were 28 times faster than in water, the resistance would be about the same, for 28 times the velocity generates 28 times 28 times (= 784 times) the resistance.

Action and reaction.—Action and reaction are equal and opposed to each other. This law not only prevails in reference to forces produced by contact, but also in the so-called forces of attraction and repulsion; amongst which the magnetic force and gravity itself may be ranked. The force with which the moon is attracted towards the earth (gravitation) is equal to that with which the moon reacts upon the earth. The force with which a workman draws or pushes at a machine, &c., reacts upon the workman and strives to move him in the opposite direction. When a body impinges against another, the pressures are reciprocally equal on each of the bodies.

Effects of continued forces—uniformly accelerated motion.—One cannot fail to be struck with the different degrees of rapidity with which bodies fall through the air. A piece of gold falls rapidly, and a dry leaf very slowly; and the popular reason for this difference is, that the gold is heavy and the leaf light: this, however, is not the true reason, for if the gold be beaten out into a thin leaf, neither its absolute nor its specific weight is diminished, but the time of its descent through the air is greatly prolonged. The fact is, that every body falling through a fluid is continually subject to two opposite forces; 1st, its *weight*, which is constantly uniform, and acting alone would constantly accelerate the fall, and 2d, the *fluid resistance.* Now the gold presenting a larger surface when beaten out than in the lump, far more resistance is opposed to the leaf than to a thick piece of equal weight, moving with equal velocity.

The fall of a heavy body from a height is a uniformly accelerated motion, because the attraction of the earth, which is the cause of its fall, never ceasing to act, the body gains at each instant of its fall a new impulse, whereby it receives additional velocity, so that its final velocity is the aggregate of all the infinitely small but *equal* increments of velocity thus communicated. Hence, the velocity of a falling body at the end of two seconds is twice that which it had at the end of one; at the end of three seconds three times that which it had at the end of one, and so on. Now, it has been ascertained that a body falling freely through space by the force of gravity acquires at the end of the first second a velocity such as would carry it, without any assistance from gravity, through about 32 feet during the second second. This is the *final velocity* of the body after one second. But during this second, the body passes gradually from a state of rest through various increasing degrees of speed, until it acquires a velocity equal to 32 feet per second. Its *average* speed, therefore, during the whole first second will be the arithmetical mean between its starting velocity, which is 0, and its final velocity, which is 32 feet per second. This mean is 16 feet per second; consequently, the space actually fallen through during this one second must be 16 feet. During the second second, the body starting with the velocity of 32 feet acquired during the first second, falls through 32 feet, and also through another 16 feet due to the action of its weight during this one second only. At the end of the second second the final velocity is twice that at the end of the first second; so that during the third second the body would move through 64 feet, if subject to no force, i. e., if its weight had ceased to act; but as this force continues to act, and would, during a second, move it through 16 feet, (if it had *no* velocity at starting,) the whole space described during this second will be 80 feet, viz., 64 feet by its *previously acquired* velocity, and 16 by that gradually added during this third second.

Hence, it appears that the time occupied in falling, and the *final* velocity, are proportional to each other; and that an increase in one is necessarily attended by a proportional increase in the other. Now, we have seen that the *average* velocity, during any fall, is exactly half the *final* velocity, for it is the mean between the velocity at starting, viz. 0, and that final velocity; hence, any increase in the time of falling, is attended by a proportional increase in the *average* speed during the whole fall. But the space fallen through is jointly proportional to the time occupied and the average velocity; consequently,

when the time is increased in any proportion, (say doubled,) the body falls, not only twice as long, but also twice as fast, and must therefore fall through *four* times the distance. So, also, if one body falls three times as long as another, it also falls with three times the average speed, and consequently falls altogether *nine* times the distance. The distance fallen must always be proportional to the square of the time occupied.

We thus get an easy rule for determining the space through which a body has fallen, simply by knowing the time occupied by the fall, and multiplying the square of this by the number of feet through which a body falls in one second. The same rule will apply to any number of seconds, whole or fractional.

To show more clearly how this law is derived from the *uniformity* of the accelerating force, take the *length* of any figure to represent the *time* of the whole fall, which divide into any convenient number of parts; and make the *breadth* of the figure, at each of those divisions, represent the *velocity* at the corresponding instant of the fall. Then the *area* of the figure, or of any portion thereof, will represent the *distance fallen through* during the corresponding part of the time; for this distance is jointly proportional to the *time* and the *average velocity*, just as the area of a figure is jointly proportional to its *length* and its *average breadth*. Let us draw such a figure, then, in which the breadth at the commencement is 0, and increases uniformly, i. e. by equal additions, for equal additions to the length. By observing the relations between its breadths at different points, and also between the areas of the whole and different portions of it, and the areas they *would* have if their breadth continued equal throughout their length, we may learn all that has been stated above, by simply substituting *time* for *length*, *velocity* for *breadth*, and *distance fallen* for *area*. The following is an example:—

A body falling freely during 5 seconds:

		Ft.	Tot. Fall.
Starting with a velocity..........................	0		
Falls during the 1*st second*................	16 = ...	16	16
Acquiring a velocity of	32 feet per second.		
Falls during the 2*d second*	32 + 16 = ...	48	64
Acquiring a velocity of twice 32, or.........	64 feet per second.		
Falls during the 3*d second*..................	32 + 32 + 16 = ...	80	144
Acquiring a velocity of $3 \times 32 =$	96 feet per second.		
Falls during the 4*th second*................	32 + 32 + 32 + 16 = ...	112	256
Acquiring a velocity of $4 \times 32 =$	128 feet per second.		
Falls during the 5*th second*................	32 + 32 + 32 + 32 + 16 = ...	144	400
Acquiring a velocity of $5 \times 32 =$	160 feet per second.		

These laws are not confined to the motion of *falling*, but apply equally to every uniformly accelerated motion, *i. e.* every motion produced by an uniform force or pressure. In every such motion, the velocities, at any different instants, are proportional to the times elapsed since the beginning of the motion; the average velocity is half the final velocity; the space described during successive equal intervals are as the series of odd numbers, 1, 3, 5, 7, &c.; and the whole spaces described from the beginning of the motion are as the squares of the times taken to describe them. But the numerical data will be different in each case of such motion; that is to say, the velocity acquired in a given time, or the time occupied in acquiring a given velocity, will vary in each case from the effects of fluid resistance and friction.

To submit all the laws which have thus been expounded to the test of direct experiment, is the object of Atwood's machine, which see, Fig. 3.

Uniformly retarded motion.—Whatever has been stated respecting *uniformly accelerated* motion, will be found equally applicable to the converse case of *uniformly retarded* motion. As in the former case the velocity increased by equal *additions* in equal times, so in this case it is reduced by equal *losses* in equal times; and if the force be the same, the velocity *lost* in any unit of time (such as a second) will be equal to that *gained* in a similar unit in the former case. Thus, when a body is projected or thrown directly upwards, and then left to the action of gravity, it rises during any second 32 *feet less* than during the previous second, until its velocity is reduced to 0, and then to a motion in the contrary direction, when the same law continues unaltered, for the body gains (like any other falling body) 32 feet of downward motion per second.

The composition of motions.—It is a physical law of great importance and simplicity, that the *dynamical effects of forces are proportional to their statical effects.* The same force which *balances* another force of twice the amount, will also, when unbalanced, produce twice as much motion: that is to say, it will either (I.) impart to *twice* as much matter the *same* velocity in the *same* time; or (II.) it will impart to the *same* matter *twice* the velocity in the *same* time; or (III.) it will impart to the *same* matter the *same* velocity in *half* the time. It must be distinctly understood that this is a physical fact, or law of nature,—not a fact to be learnt by *deduction*, but by *induction* from experiments.

The doctrine of the parallelogram of forces is applicable to the *composition of motion.* Thus, suppose the body x, as in Fig. 1752, to be acted on at once by three forces in the directions of the arrows A B C; that A acting alone would in one unit of time (such as a second, or an hour) drive the body to

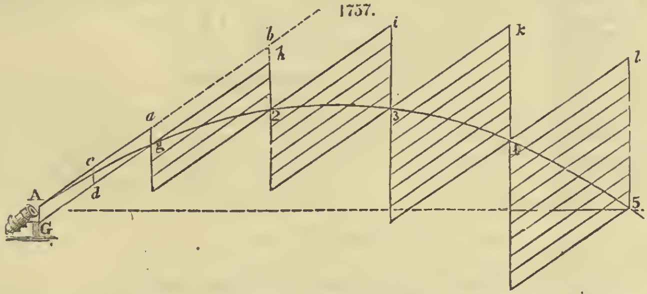
a; that B acting alone (and being weaker than A) would in the same length of time drive the body no further than b; and that C, in like manner, acting alone, would cause it in the same length of time to reach c. Now, to find the effect of A and B united, complete the parallelogram $x\,a\,d\,b$, and its further angle d is the point to which the body will be sent by the joint action of both A and B, in the *same length of time* that it would have occupied in reaching a by the action of A only, or in reaching b by the action of B only. This will be true, whether the two forces act both in the same manner or in different manners, however varied; but in the latter case, although the body arrives at the point d just as soon, yet it will travel thither by a different route. In order that it may move along the straight line $x\,d$, it is necessary that the two forces act in the same manner; such, for example, as by an instantaneous impulse, which will cause a uniform motion; or both may act continuously and uniformly, so as to produce a uniformly accelerated motion, (like that of falling bodies;) or both forces may act with a continually varying intensity, both increasing or diminishing at the same rate, and the motion will still be rectilinear. But if one force be instantaneous and the other continuous, or one uniformly continued and the other varying in intensity, or both varying by different laws, so as not to preserve constantly the same ratio to each other, then the path of the body will be a curve, still, however, conducting it eventually to the point d, in the same time that the force A would have taken to send it to a, or B to b.

But suppose the third force C to act on the body x, and to be capable of carrying it to c in the same time that A and B jointly would carry it to d. We have only to complete the parallelogram $x\,d\,e\,c$, to find that by the combined action of all three forces the body will be sent in the same unit of time to e.

It is another remarkable consequence of this law, that whether we regard the directions of the three forces as being all in one plane, or in different planes, the law is equally true.

This most important law as regards motions, may therefore be simply expressed in the following terms:—that by any number of forces acting together for a given length of time, a body is brought to the same place as if each of the forces, or one equal and parallel to it, had acted on the body separately and successively for an equal length of time.

1757.



Let us now consider the effect of the composition of a *uniform* with a *uniformly accelerated* motion, the two being in different but not opposite directions, as in the case of *projectiles*, i. e. bodies thrown horizontally, or obliquely. To simplify the questions, let us suppose them subject to no other force than gravity, which continually *deflects* them out of the straight line which they would otherwise describe, and which is called the *line of projection.* Now it matters not whether this line be horizontal, inclining upwards, or inclining downwards, it will constantly be found that the vertical depth of the projectile below this line at any moment, is equal to the depth which it would have fallen during the time which has elapsed since its projection. Thus, if a cannon-ball be shot from A in the direction A b, Fig. 1757, and its original velocity be such as would carry it through the space A a during one second, then, if not subject to gravity, it would proceed in a straight line and arrive at a in one second, at b in two seconds, and so on. But gravity alone would cause it during the first second to fall 16 feet, (say from A to G.) By completing the parallelogram A a G g, then, we see that after one second the body will have arrived at g, exactly as if it had first been carried by the projectile force during one second to a, and then fallen during one second to g. In the same way, during the next second, the ball moves in the direction of projection through the space $a\,b$, or $g\,h$, and in the direction of gravity through $h\ 2 = 3$ times 16 feet. In the third second it advances as much as before, viz. 2 i, and falls 5 times 16 feet, bringing it to the point 3. In the fourth and fifth seconds it advances in the direction 3 k, or 4 l, as much as in the first second, but falls 7 times and 9 times as much, thus arriving at the points 4 and 5. Now it results from this, that the points A, g, 2, 3, 4, 5, are necessarily situated on a curved line of that kind called a *parabola*, and if the place of the ball at any other moments (however numerous) be found, all these points will likewise fall on the same curve.

The distance from A, at which the ball again crosses the horizontal line A 5, is called the *horizontal range.* This will be the greatest possible, with a given velocity of projection, when the body is projected at an angle of 45° with the horizon. In this case the greatest height attained is just one-fourth of the range. So that, as the time of flight is twice the time of falling that height, (or the exact time of falling four times that height,) the ball arrives at its destination in the same time as if it had fallen a like distance vertically by the action of gravity. Hence the range (in feet) is 16 times the square of the number of seconds in the flight. It is also remarkable that the range will be diminished equally by equal deviations from this angle, whether above or below it. Thus a mortar will (with the same charge) carry to the same distance, on a level plain, when it is inclined 40° as when inclined 50°; or the same at 10° as at 80°.

We have hitherto regarded gravity as a *parallel* force. But if the range of a projectile amounted t. some miles, so as to bear a measurable ratio to the earth's radius, it would be necessary, in finding its

path *very exactly*, to regard it as a *central* force, by making the lines A G, $a\,g$, b 2, i 3, k 4, l 5, no longer parallel, but such as would, if continued, meet at the earth's centre.

The effect of this change is to convert the parabola into one extremity of a very long and narrow *ellipse*, whose other extremity passes round the earth's centre, and has its focus at that centre. Such, indeed, is the curve described by every projectile.

It is in this manner, then, that the *moon* revolves in an ellipse of small eccentricity, of which one focus is occupied by the earth's centre. Her deflection from the straight line is due to a force exactly with that which deflects a projectile; which force varies in intensity *inversely* as the *square* of her *distance from the earth's centre* varies. Now, if we calculate in this manner her deflection or fall, supposing her situated at *our own* distance from the earth's centre, we shall find it would be exactly 16 feet in a second, 64 feet in two seconds, &c., &c., like that of our projectiles or falling bodies.

The observance of exactly the same laws in the motions of the satellites of the great planets, shows that a force of the same kind is exerted towards *their* centres. Moreover, it has been established by the joint labors of the two Herschels, that the same force regulates the motions of the unmeasurably distant *double stars*.

It appears, then, that attraction or gravity is a universal property common to all matter, every particle in the universe attracting every other particle; and there is no irregularity in the motions of the bodies of the solar system, no deviations appreciable by the most delicate astronomical observations, which has not been explained, and its period and amount accurately calculated on the principles of universal gravitation, according to the laws discovered by Kepler.

Central force.—The tendency which bodies in motion have to recede from its centre is called the *centrifugal force:* the tendency to approach the centre of motion, is called the centripetal.

The central force of a body describing a circle with a uniform velocity is directly proportional to the square of the velocity, and inversely as the radius of the circle. The doctrine of central forces has its practical application in astronomy; the force by which the planets describe their orbits is a central force, directed to the sun as a centre; and the forces by which the planetary motions are sustained, vary inversely as the squares of the distances of the planet from that body.

In the case of fly-wheels, the succeeding rules will be found sufficient:

$$\text{(A.)}\qquad \frac{\text{velocity}^2 \times \text{weight}}{\text{radius} \times 32} = \text{centrifugal force.}$$

(B.) Divide the velocity by 4·01, square the quotient, and divide by the diameter: this last quotient multiplied by the weight, will give the centrifugal force.

$$\text{(C.)}\ \frac{\text{Number of revolutions per minute}^2 \times \text{diameter}}{5870} \times \text{weight} = \text{the centrifugal force.}$$

$$\text{(D.)}\ \frac{\text{velocity}^2 \times \text{radius}}{\text{centrifugal force} \times 3^2} = \text{radius.}$$

$$\text{(E.)}\ \frac{\text{radius} \times \text{centrifugal force} \times 32}{\text{velocity}^2} = \text{weight.}$$

$$\text{(F.)}\ \sqrt{\left(\frac{\text{radius} \times \text{centrifugal force} \times 32}{\text{weight}}\right)} = \text{the velocity.}$$

The following examples will illustrate the application of these rules.

What is the centrifugal force of the rim of a fly-wheel moving with a velocity of $32\frac{1}{2}$ feet in a second, and whose diameter is 20 feet.

(By B.) $\frac{32\frac{1}{6}}{4·01} = 8·02$ then $\frac{8·02^2}{20} = 3·216$, which multiplied by the weight of the rim, will give the centrifugal force.

A grindstone makes 120 revolutions in the minute, the radius of the circle of its motion being 2 feet, and its weight 6 pounds.

$$\text{(By C.)}\ \frac{120^2 \times 4}{5870} \times 6 = \frac{57600}{5870} \times 6 = 9·81 \times 6 = 58·86 = \text{the centrifugal force.}$$

A fly-wheel makes 65 revolutions per minute, its diameter being 12 feet, and the weight of the rim one ton, the weight of the entire fly being $1\frac{1}{2}$ tons, the circle of gyration is 5·5 feet from the axis, the wheel consisting of two halves joined by bolts capable of resisting a pressure of 4 tons, wherefore,

$$\frac{12 \times 3·1416 \times 65}{60} = 40·84 = \text{velocity in feet per second.}$$

$$\text{And (by A.)}\ \frac{40·84^2 \times 1}{32 \times 6} = 8·688 \text{ tons, the centrifugal force.}$$

And (by F.) $\sqrt{\left(\frac{32 \times 4 \times 5·5 \times 2}{1·5}\right)} = \sqrt{\frac{1403}{1·5}} = 30·638$, and since $2 \times 5·5 \times 3·1416 = 34·5576 =$ the circle of gyration, therefore, $\frac{30·0638 \times 60}{34·5576} = 52.197$, the number of revolutions per minute, which would cause the fly to burst asunder.

FORGE. The workshop in which iron is hammered and shaped by the aid of heat. The term is generally applied to the places in which these operations are carried on upon the comparatively small scale; the great workshops in which iron is made malleable for general purposes being called a

shingling mill. A common forge consists of the hearth or fireplace, which is merely a cavity in masonry or brickwork well lined with fine clay or brick, upon which the ignited fuel is placed, and upon the back or side of which a powerful blast of air is driven in through the nozzle of a double-blasted bellows, which, in a common forge, is generally worked by a hand lever. Forges are sometimes constructed so as to be portable, when the bellows is most conveniently placed under the hearth; these are used in ships, and for various jobs on railways, &c.

FORGING—*Iron and steel.* The heaviest works are generally heated in air furnaces of various descriptions, some of which resemble, but greatly exceed in size, those employed in the works where iron is manufactured, and in which the process of forging may be truly considered to commence with the first blow given upon the *ball*, as it leaves the puddling furnace for being converted into a *bloom.*

The paddle-shafts of the largest steamships are wrought by successive additions at the one end, as follows: A slab of iron, technically called "a use," is welded on one side close to the end, and when drawn down to the common thickness, the additional matter becomes thrown into the length; the next *use* is then placed on the adjoining side of the as yet square shaft, and also drawn into the length, and so on until the full measure is attained.

First, the "*heat*" has a long iron rod attached to it in continuation of its axis, to serve as a "*porter*" or guide rod; the mass is suspended under a traversing crane at that point where it is nearly equipoised; the crane not only serves to swing it round from the fire to the hammer, but the traverse motion also moves the work endways upon the anvil, and small changes of elevation are sometimes effected by a screw adjustment in the suspending chain. The circular form is obtained by shifting the work round upon its axis by means of a cross level fixed upon the porter, and moved by one or two men, so as to expose each part of the circumference to the action of the helve; this is readily done as the crane terminates in a pulley, around which an endless band of chain is placed, and the work lies within the chain, which shifts round when the work is turned upon the anvil.

A similar mode of work is adopted on a smaller scale for many of the spindles, shafts, and other parts of ordinary mechanism, which are forged under the great hammer, often of several bars piled together and *fagoted;* a suitable term, as they are frequently made of a round bar in the centre, and a group of bars of angular section, called *mitre iron,* around the same, which are temporarily wedged within a hoop, somewhat after the manner of a fagot of wood. Such works are also made of scrap-iron.

A number of these fragments are enveloped in an old piece of sheet-iron, and held together by a hoop; the mass is raised to the welding heat in a blast or air furnace, and the whole is consolidated and drawn down under the tilt-hammer; one long bar that serves as the porter being welded on by the first blow. The mingling of the fibres in the scrap-iron is considered highly favorable to the strength of the bar produced. The scrap-iron is sometimes twisted during the process of manufacture, to lay all the filaments like a rope, and prevent the formation of *spills*, or the longitudinal dirty seams found on the surface of inferior iron.

The long furnaces are particularly well suited to straight works and bars, but when the objects get shorter and of more complex figures, the open fire or ordinary smith's hearth is employed. This, when of the largest kind, is a trough or pit of brickwork about six feet square, elevated only about six inches from the ground; the one side of the hearth is extended into a vertical wall leading to the chimney, the lower end of which terminates in a hood usually of stout plate iron, which serves to collect the smoke from the fire. The black wall of the forge is fitted with a large cast-iron plate, or a *back*, in the centre of which is a very thick projecting nozzle also of iron, perforated for admitting the wind used to urge the fire; the aperture is called the *tuyere.*

The blast is sometimes supplied from ordinary bellows of various forms; at other times by enormous air-pumps, which lead into a cylinder or regulator, the piston of which is loaded with weights, so as to force the air through pipes all over the smithy, and every fire has a valve to regulate its individual blast; but the more modern and general plan is the revolving fan, also worked by the engine, the blast from which is similarly distributed.

In some cases the cast-iron forge back is made hollow, that a stream of water may circulate through it from a small cistern; the *water-back* is thereby prevented from becoming so hot as the others, and its durability is much increased. In other cases the air, in its passage from the blowing apparatus, flows through chambers in the back plate so as to become heated in its progress, and thus to urge the fire with *hot blast*, which is by many considered to effect a very great economy in the fuel.

Some heavy works of rather complex form, such as anchors, are most conveniently managed by hand forging; many of these require two gangs of men with heavy sledge hammers, each consisting of six to twelve men, who relieve each other at short intervals, as the work is exceedingly laborious.

The square shanks of anchors are partly forged under a vertical hammer of very simple construction, called a "*monkey.*" It consists of a long iron bar running very loosely through an eye or aperture several feet above the anvil, and terminating at foot in a mass of iron, or the ram. The hammer is elevated by means of a chain, attached to the rod and also to a drum overhead, which is put into geer with the engine, and suddenly released by a simple contrivance, when the hammer has reached the height of from two to five feet, according to circumstances. The ram is made to fall upon any precise spot within a horizontal range of some twenty inches from the central position by two slight gye-rods, hooked to the ram and placed at right angles. This contrivance is far more effective than the blows of the sledge hammers, and although now but little used is perhaps more suitable to such purposes than the helve or lift hammer, which always ascends to one height, and falls upon one fixed spot.

Nasmyth's steam hammer is now almost entirely used in forging anchors: it has very much shortened the process, and makes more perfect work.

The square shank of the anchor, and works of the same section, are readily shifted the exact quarter circle, as the sling-chain is made with flat links, each a trifle longer than the side of the square of the work, which therefore bears quite flat upon one link, and when twisted it shifts the chain the space of a link, and rests as before.

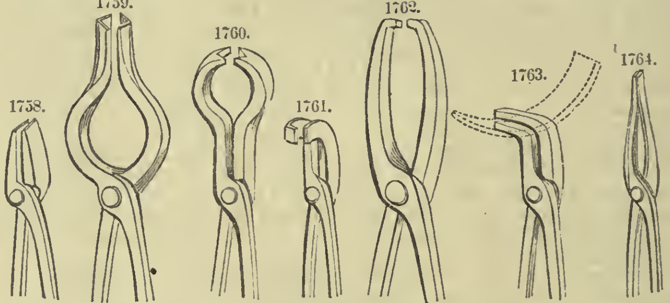
Many implements and tools, such as shovels, spades, mattocks, and cleavers, are partly forged under the tilt-hammer; the preparatory processes, called moulding, which include the insertion of the steel, are done by ordinary hand forging. The objects are then spread out under the broad face of the tilt-hammer, the workman in such cases being sometimes seated on a chair suspended from the ceiling, and by paddling about with his feet, he places himself with great dexterity in front or on either side of the anvil with the progressive changes of the work; the concluding processes are mostly done by hand with the usual tools. A similar arrangement is also adopted in tilting small sized steel.

With the reduction of size in the objects to be forged, the number of hands is also lessened, and the crane required for heavy work is abandoned for a chain or sling from the ceiling; but for the majority of purposes two men only are required, when the work is said to be *two-handed.*

As the works to be forged become smaller, the hearth is gradually lessened in size, and more elevated, so as to stand about two and a half feet from the ground: it is now built hollow, with an arch beneath serving as the ash-pit. The single hearths are made about a yard square, and those forges which have two fires under the same hood, measure about two yards by one; a double trough to contain water in the one compartment and coals in the other, is usually added, and the ordinary double bellows are used.

Figs. 1765 and 1758 are called *flat-bit* tongs; these are either made to fit very close as in Fig. 1758, for thin works, or to stand more open as in Fig. 1765, for thicker bars, but always parallel; and a ring or coupler, is put upon the handles or *reins*, to maintain the grip upon the work. Others of the same general form are made with hollow half-round bits; but it is much better they should be angular, like the ends of Fig. 1759, as then they serve equally well for round bars, or for square bars held upon their opposite angles. Tongs that are made long, and swelled open behind, as in Fig. 1759, are very excellent for general purposes, and also serve for bolts and similar objects, with the heads placed inward. The *pincer* tongs, Fig. 1760, are also applied to similar uses, and serve for shorter bolts.

1758. 1759. 1760. 1761. 1762. 1763. 1764.



1765.

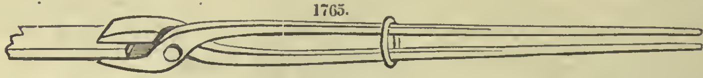


Fig. 1761 represents tongs much used amongst the cutlers; they are called *crook-bit* tongs; their jaws overhang the side, so as to allow the bar of iron or steel to pass down beside the rivet, and the nib at the end prevents the rod from being displaced by the jar of hammering. Fig. 1762, or the *hammer* tongs, are used for managing works punched with holes, such as hammers and hatchets; as the pins enter the holes and maintain the grasp.

Fig. 1763, or *hoop* tongs, are very much used by ship-smiths, for grasping hoops and rings, which may be then worked either on the edge, when laid flat on the anvil, or on the side, when upon the beak-iron; and lastly, Fig. 1764 represents the smith's *pliers*, or light tongs, used for picking up little pieces of iron, or small tools and punches.

In addition to the hearth, anvil, and tongs, the smithy contains a number of chisels, punches, and swages or striking tools, called also top and bottom tools, of a variety of suitable forms and generally in pairs; these may be considered as reduced copies of the grooves turned in the rollers, and occasionally made on the faces of the tilt-hammers of the iron-works for the production of square, flat, round, T-form iron, angle iron, and railway bars, as referred to. In fitting the hazel-rods to the top tools, the rods are alternately wetted in the middle of their length, and warmed over the fire to soften them; that portion is then twisted like a rope, and the rod is wound once round the head of the tool, and retained by an iron ferrule or couples; a rigid iron handle would jar the hand.

When these tools are used for large works, a square plate of sheet-iron, with a hole punched in the middle of it, is put on the rod towards the tool, to shield the hand of the workman from the heat; and it not unfrequently happens with such large works that the rod catches fire, and the tool is then dipped at short intervals in the slake trough to extinguish it.

The smith who works without any helpmate is much more circumscribed as to tools, and he is from necessity compelled to abandon all those used in pairs, unless the upper tools have some mechanical guide to support and direct them. In addition to the anvil he only uses the fixed cutter and heading tools; he may occasionally support the end of the tongs in a hook attached to his apron-string, or suspended from his neck, whilst he applies a hand-chisel, a punch, or a name-mark in the left hand, and strikes with the hammer held in the right.

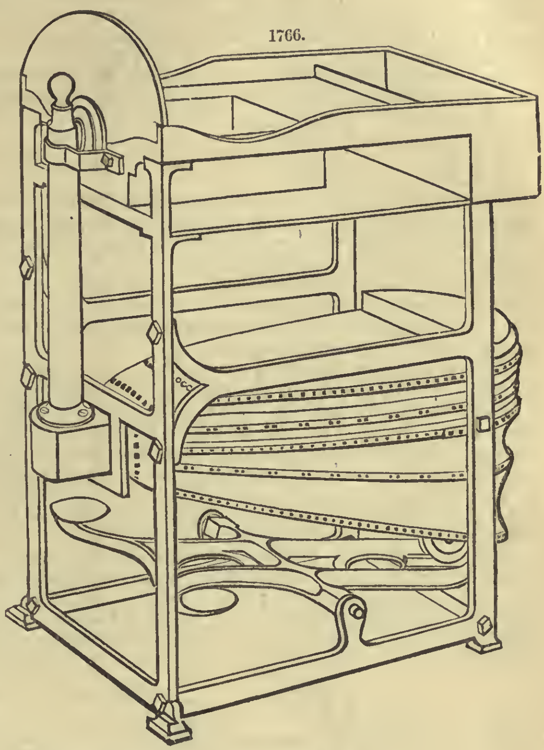
Attempts to work small tilt-hammers with the foot have been found generally ineffective, as the attention of the individual is too much subdivided in managing the whole, neither is his strength sufficient for a continued exertion at such work; but the "*Oliver*" is one of the best tools of this class.

A portable forge of suitable dimensions for single hand-forging, and made entirely of iron, is represented in Fig. 1766. The bellows are placed beneath the hearth and worked by a treadle.

This forge is also occasionally fitted with a furnace for melting small quantities of metal, and with various apparatus for other applications of heat, such as soldering, either with a small charcoal fire, or a lamp and blow-pipe, which are likewise urged with the bellows. These applications, and also that of hardening and tempering tools, are much facilitated by the bellows being worked with the foot, as it leaves both hands at liberty for the management either of the work or fire.

The forge represented is sufficiently powerful for a moderate share of those works which require the use of the sledge-hammer.

1766.



The ordinary fuel for the smith's forge is coal, and the kinds to be preferred are such as are dense and free from metallic matters, as these are generally accompanied with sulphur, which is highly detrimental.

In forging, the iron or steel is in almost every case heated to a greater or less degree, to make it softer and more malleable by lessening its cohesion; the softening goes on increasing with the accession of temperature, until it arrives at a point beyond that which can be usefully employed, or at which the material, whether iron or steel, falls in pieces under the blows of the hammer, but which degree is very different with various materials, and even with varieties bearing the same name.

Pure iron will bear almost unlimited degree of heat; the hot-short iron bears much less, and is in fact very brittle when heated; other kinds are intermediate. Of steel, the shear-steel will generally bear the highest temperature, the blistered-steel the next, and the cast-steel the least of all; but all these kinds, especially cast-steel, differ very much according to the processes of manufacture, as some cast-steel may be readily welded, but it is then somewhat less certain to harden perfectly.

The smith commonly speaks of five degrees of temperature, namely:

The black-red heat, just visible by daylight;

The low-red heat;

The bright-red heat, when the black scales may be seen;

The white heat, when the scales are scarcely visible;

The welding heat, when the iron begins to burn with vivid sparks.

Steel requires on the whole very much more precaution as to the degree of heat than iron; the temperature of cast-steel should not generally exceed a bright-red heat, that of blistered and shear-steel that of a moderate white heat. Although steel cannot in consequence be so far softened in the fire as iron, and is therefore always more dense and harder to forge, still from its superior cohesion it bears a much greater amount of hard work under the hammer, when it is not over-heated or burned; but the smallest available temperature should be always employed with this material, as in fact with all others.

The cracks and defects in iron are generally very plainly shown by a difference in color at the parts when they are heated to a dull red; this method of trial is often had recourse to in examining the soundness both of new and old forgings.

When a piece of forged work is required to be particularly sound, it is a common practice to subject every part of the material in succession to a welding heat, and to work it well under the hammer, as a repetition of the process of manufacture to ensure the perfection of the iron: this is technically called, *taking a heat over it;* in fact, a heat is generally understood to imply the welding heat. For a two-inch shaft of the soundest quality, two and a half inch iron would be selected, to allow for the reduction in the fire and the lathe; some also twist the iron before the hammering to prevent it from becoming "*spilly.*"

The use of sand sprinkled upon the iron is to preserve it from absolute contact with the air, which would cause it to waste away from the oxidation of its surface, and fall off in scales around the anvil. If the sand is thrown on when the metal is only at the full red heat, it falls off without adhering; but when the white heat is approached, the sand begins to adhere to the iron; it next melts on its surface, over which it then runs like fluid glass, and defends it from the air; when this point has been rather exceeded, so that the metal nevertheless begins to burn with vivid sparks and a hissing noise like fireworks, the welding temperature is arrived at, and which should not be exceeded. The sparks are

however, considered a sign of a dirty fire or bad iron, as the purer the iron the less it is subject to waste or oxidation in the course of work.

In welding two pieces of iron together, care must be taken that *both* arrive at the welding heat at the same moment; it may be necessary to keep one of the pieces a little on one side of the most intense part of the fire, (which is just opposite the blast,) should the one be in advance of the other. In all cases a certain amount of *time* is essential; otherwise, if the fire be unnecessarily urged, the outer case of the iron may be at the point of ignition before the centre has exceeded the red heat. In welding iron to steel, the latter must be heated in a considerably less degree than the iron, the welding heat of steel being lower from its greater fusibility; but the process of welding will be separately considered under a few of its most general applications, when the ordinary practice of forging has been discussed, and to which we will now proceed.

The general practice of forging works from the bar of iron or steel, are for the most part included in the three following modes; the first two occur in almost every case, and frequently all three together; namely,

By *drawing-down*, or reduction:

By *jumping* or *upsetting*, otherwise thickening and shortening:

By *building-up*, or welding.

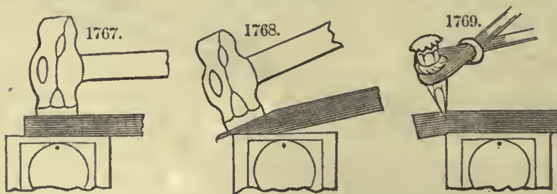
To meet the variety of cases which occur, the smith has hammers in which the panes are made in different ways, either at right angles to the handle, parallel with the same, or oblique.

In order to obtain the same results with more precision and effect, tools of the same characters, but which are struck with the sledge-hammer, are also commonly used: those with flat faces are made like hammers, and usually with similar handles, except that for the convenience of reversing them they are not wedged in; these are called *set-hammers;* others which have very broad faces, are called *flatters;* and the top tools with narrow round edges like the pane of the hammer, are called *top-fullers;* they all have the ordinary hazel-rods.

When the sides of the object are required to be parallel, and it is to be reduced both in width and thickness, the flat face of the hammer is made to fall parallel with the anvil, as represented in Fig. 1767; or oblique for producing taper pieces, as in Fig. 1768; and action and reaction being equal, the lower face of the work receives the same absolute blow from the anvil as that applied above by the hammer itself; it is not requisite, therefore, (for works of moderate dimensions,) to present every one of the four sides to the hammer, but any two, at right angles to each other.

The smith must acquire the habit of *feeling* when the bar lies perfectly flat upon the anvil, by holding it slenderly, leaving it almost to rotate in his grasp, or in fact to place *itself.* Next he must cause the hammer to fall flat upon the work.

It would be desirable practice to hammer a bar of cold iron, or still better, one of steel, as there would be more leisure for observations; the indentations of the hammer could be easily noticed; and if the work, especially steel, were held too tightly, or without resting fairly on the anvil, it would indicate the error by additional noise and by jarring the wrist; whereas, when hot, the false blows or positions would cause the work to get out of shape, without such monitorial indications.



As to the best form of the hammer, there is much of habit and something of fancy. The ordinary hand-hammer is represented in Figs. 1767 and 1768; but cutlers, and most tool makers, prefer the hammer without a pane, or narrow edge, and with the handle quite at the top, the two forming almost a right angle, or from that to about eighty degrees; and sometimes the head is bent like a portion of a circle. Similar but much heavier hand-hammers, occasionally of the weight of 12 or 14 pounds, are used by the spade-makers for planishing; but the work being thin and cold, the hammer rises almost exclusively by the reaction, and requires little more than guidance. Again, the farriers prefer for some parts of their work, a hammer the head of which is almost a sphere; it has two flat faces, one rounded face for the inside of the shoe, and one very stunted pane at right angles to the handle, used for drawing down the clip in front of the horse-shoe; in fact, nearly a small volume might be written upon all the varieties of hammers.

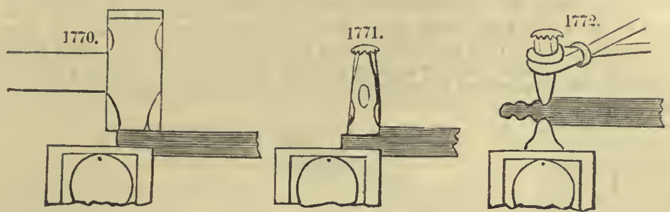
Suppose it required to *draw down* six inches of the end of a square or rectangular bar of iron or steel; the smith will place the bar across the anvil with perhaps four inches overhanging, and not resting quite flat, but tilted up about a quarter or half an inch at the near side of the anvil, as in Fig. 1768, but less in degree, and the hammer will be made to fall as there shown, except that it will be at a very small angle with the anvil.

In smoothing off the work, the position of Fig. 1767 is assumed; the work is laid flat upon the anvil, and the hammer is made to fall as nearly as possible horizontally; a series of blows are given all along the work between every quarter turn, the hammer being directed upon one spot, and the work drawn gradually beneath it.

In drawing down the tang or taper-point of a tool, the extreme end of the iron or steel is placed a little beyond the edge of the anvil, as in Fig. 1768, by which means the risk of indenting the anvil is entirely removed, and the small irregular piece in excess beyond the taper is not cut off until the

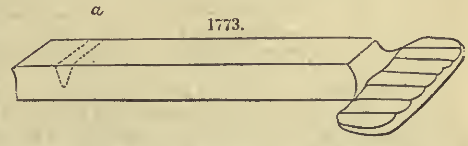
tang is completed. Fig. 1769 shows the position of the chisel in cutting off the finished object from the bar of which it formed a part; that is, the work is placed between the edge of the anvil and that of the chisel immediately above the same; the two resemble in effect a pair of shears.

When it is required to make a *set-off*, it is done by placing the intended shoulder at the edge of the anvil: the blows of the hammer will be effective only where opposed to the anvil, but the remainder of the bar will retain its full size and sink down, as represented in Fig. 1770. Should it be necessary



to make a shoulder on both sides, a flat-ended set-hammer, struck by the sledge, is used for *setting* down the upper shoulder, as in Fig. 1771, as the direct blows of the hammer could not be given with so much precision. In each of these cases some precaution must be observed, as otherwise the tools, although so much more blunt than the chisel, Fig. 1769, will resemble it in effect, and cripple or weaken the work in the corner; on this account the smith's tools are rarely quite sharp at the angles: this mischief is almost removed when the round fullers, Fig. 1772, are used for reducing the principal bulk, and the sharper tools are only employed for trimming the angles with moderate blows.

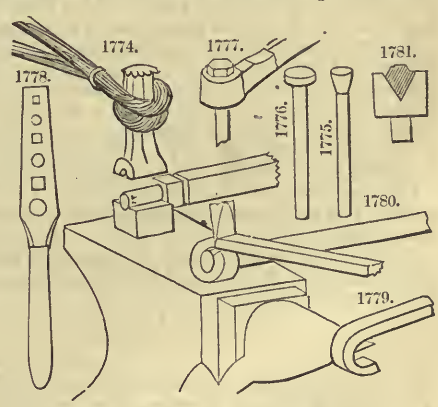
When the iron is to be set down, and also spread laterally, as in Fig. 1773, it is first nicked with a round fuller as upon the dotted line at *a*, and the piece at the end is spread by the same tool, upon the short lines of the object, or parallel with the length of the bar: the first notch greatly assists in keeping a good shoulder at the bottom of the part set down, and the lines are supposed to represent the rough indentations of the round fuller before the work is trimmed up.



There is often considerable choice of method in forging, and the skilful workman selects that method of proceeding which will produce the result with the least portion of manual labor.

Figs. 1775, 1776, and 1777, explain these processes of making an ordinary screw-bolt; the latter is a single tool, but the heading-tool, Fig. 1778, with several holes, is also used.

In upsetting the end of the work, if more convenient, it may be held horizontally across the anvil, and struck on the heated extremity with the hand-hammer; or it can be jumped forcibly upon the anvil, when its own weight will supply the required momentum. If too considerable a portion of the work is heated, it will either bend, or it will swell generally; and therefore to limit the enlargement to the required spot, should the heat be too long, the neighboring part is partially cooled by immersing it in the water-trough, as near to the heat as admissible.



A bolt may be made by building up or welding:—An eye is first made at the end of a small rod of square or flat iron; by bending it round the beak-iron, as in Fig. 1779, it is placed around the rod of round iron, and the curled end is cut off with the chisel, as in Fig. 1780, enough iron being left in the ring, which is afterwards *welded* to the rod to form the head of the bolt, by a few quick light blows given at the proper heat; the bolt is then completed by any of the tools already described that may be preferred. A swage at the angle of sixty degrees, Fig. 1781, will be found very convenient in forming hexagonal heads, as the horizontal blow of the hammer completes the equilateral triangle, and two positions operate on every side of the hexagon; Fig. 1781 is essential likewise in forging triangular files and rods.

For the parts of mechanism in which a considerable length of two different sections or magnitudes of iron are required, the method by drawing down from the large size would be too expensive; the method by upsetting would be impracticable; and therefore a more judicious use is made of the iron store, and the object is made in two parts, of bars of the exact sections respectively. The larger bar is reduced to the size of the smaller, generally upon the beak-iron with top fullers, and with a gradual transition or taper extending some few inches, as represented in Fig. 1782; the two pieces are *scarfed* or prepared for welding.

Fig. 1782 is also intended to explain two other proceedings very commonly required in forging. Bars are bent down at right angles as for the short end or corking of the piece, Fig. 1782, by laying the work on the anvil, and holding it down with the sledge-hammer, as in Fig. 1783; the end is then bent with the hand-hammer, and trimmed square over the edge of the anvil; or when more precision

is wanted, the work is screwed fast in the tail-vice, which is one of the tools of every smith's shop, and it is bent over the jaws of the vice. When the external angle, as well as the internal, is required to be sharp and square, the work is reduced with the fuller from a larger bar to the form of Fig. 1784, to compensate for the great extension in length that occurs at the outer part, or *heel* of the bend, of which the inner angle forms as it were the centre.

The holes in Fig. 1782 for the cross-bolts are made with a rod-punch, which is driven a little more than half way through from the one side whilst the work lies upon the anvil, so that when turned over, the cooling effect of the punch may serve to show the place where the tool must be again applied for the completion of the hole; the little bit or *burr* is then driven out, either through the square hole in the anvil that is intended for the bottom tools, or else upon the holster, Fig. 1785, a tool faced with steel, and having an aperture of the same form and dimensions as the face of the punch.

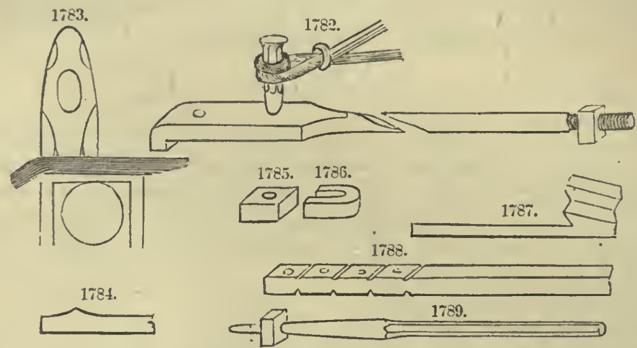

1783. 1782. 1785. 1786. 1787. 1788. 1784. 1789.

Fig. 1788 shows the ordinary mode of making the square nuts for bolts. A flat bar is first nicked on the sides with the chisel, then punched, and the rough nuts, if small, are separated and strung upon the end of the poker, (a slight round rod bent up at the end,) for the convenience of managing them in the fire, from which they are removed one at a time when hot, and finished on the triblet, Fig. 1789, which serves both as a handle, and also as the means of perfecting the holes.

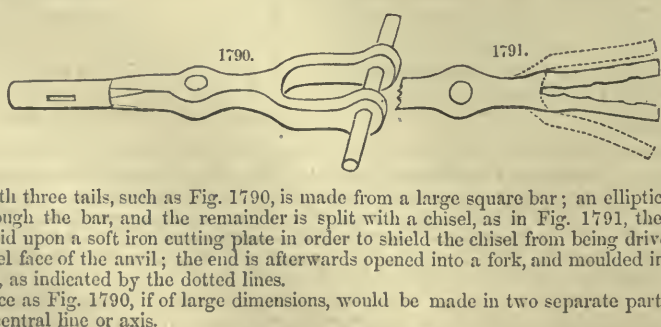
For making hexagon nuts, the flat bar is nicked on both edges with a narrow round fuller; this gives a nearer approach to the hexagon: the nuts are then flattened on the face, punched, and dressed on the triblet within the angular swage, Fig. 1781, before adverted to. Thick circular collars are made precisely in the same way, with the exception that they are finished externally with the hammer, or between top and bottom rounding tools of corresponding diameter.

It is usual in punching holes through thick pieces, to throw a little coal-dust into the hole when it is partly made, to prevent the punch sticking in so fast as it otherwise would: the punch generally gets red-hot in the process, and requires to be immediately cooled on removal from the hole.

In making a socket, or a very deep hole in the one end of a bar, some difficulty is experienced in getting the hole in the axis of the bar, and in avoiding to burst open the iron; such holes are produced differently, by sinking the hole as a groove in the centre of a flat bar by means of a fuller; the piece is cut nearly through from the opposite side, folded together lengthways, and welded. The hole thus formed will only require to be perfected by the introduction of an appropriate punch, and to be worked on the outside, with those tools required for dressing off its exterior surface, whilst the punch remains in the hole to prevent its sides from being squeezed in: this method is very good.

For punching square holes, square punches and bolsters are used, and Fig. 1786, the split bolster, is employed for cutting out long rectangular holes or mortises, which are often done at two or more cuts with an oblong punch.

When a thick lump is wanted at the end of a bar, it is often made by cutting the iron nearly through and doubling it backwards and forwards, as in Fig. 1787; the whole is then welded into a solid mass as the preparatory step.


1790. 1791.

A piece with three tails, such as Fig. 1790, is made from a large square bar; an elliptical hole is first punched through the bar, and the remainder is split with a chisel, as in Fig. 1791, the work at the time being laid upon a soft iron cutting plate in order to shield the chisel from being driven against the hardened steel face of the anvil; the end is afterwards opened into a fork, and moulded into shape over the beak-iron, as indicated by the dotted lines.

Such a piece as Fig. 1790, if of large dimensions, would be made in two separate parts, and welded through the central line or axis.

Should it happen the two arms are not quite parallel, an error that could scarcely be corrected by the hammer alone, the work would be fixed in the vice with the two tails upwards, and the one or

other of these would be twisted to its true position by a *hook wrench* or *set*, made like the three sides of a square, but the one very long to serve as a lever; it is applied exactly in the manner of a key, spanner, or screw-wrench, in turning round a bolt or screw.

Some bent objects, such as cranks and straps, are made from bar-iron, bent over specific moulds, which are sometimes made in pairs like dies, and pressed together by screw contrivances. When the moulds are single, the work is often retained in contact with the same, at some appropriate part, by means of straps and wedges; whilst the work is bent to the form of the mould by top tools of suitable kinds.

Objects of more nearly rectilinear form are cut out of large plates and bars of iron with chisels; for example, the cranks of locomotive engines are faggoted up of several bars or uses laid together, and pared to the shape: they are sometimes forged in two separate parts, and welded between the cranks; at other times they are forged out of one parallel mass, and afterwards twisted with a hook-wrench, in the neck between the cranks, to place the latter at right angles. The notches are sometimes cut out on the anvil whilst the work is red-hot; or otherwise by machinery when in the cold state.

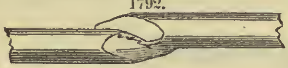
A very different method of making rectangular cranks and similar works is also recommended, by bending one or more straight bars of iron to the form; the angles, which are at first rounded, are perfected by welding on outer caps. In this case the fibre runs round the figure, whereas when the gap is cut out, a large proportion of the fibres are cut into short lengths, and therefore a greater bulk must be allowed for equal strength: this method is however seldom used.

All kinds of levers, arms, brackets, and frames, are made after these several methods, partly by bending and welding, and partly by cutting and punching out; and few branches of industry present a greater variety in the choice of methods, and which call the judgment of the smith continually into requisition.

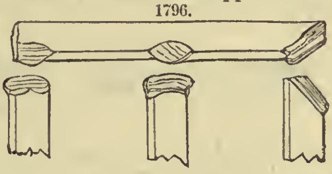
There are several ways of accomplishing the operation of welding, and which bear some little analogy to the joints employed in carpentry; more particularly that called scarfing, used in the construction of long beams and girders by joining two shorter pieces together endways, with sloping joints, which in carpentry are interlaced or mortised together in various ways, and then secured by iron straps or bolts. In smith's work likewise, the joinings are called *scarfs*, but from the adhesive nature of the iron when at a suitable temperature, the accessories called for in carpentry, such as glue, bolts, straps, and pins, are no longer wanted.

The scarfs required for the *shut*, are made by first upsetting or thickening the iron by blows upon its extremity, to prepare it for the loss it will sustain from scaling off, both in the fire and upon the anvil, and also in the subsequent working upon the joint. It is next rudely tapered off to the form of a flight of steps, as shown in Figs. 1792 and 1793, and the sides are slightly bevelled or pointed, as in Fig. 1793, the proportion being somewhat exceeded to render the forms more apparent.

1792.

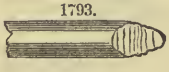


1796.

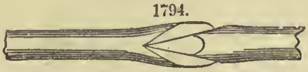


b a c

1793.



1794.



1795.

The two extremities are next heated to the point of ignition; and when this is approached, a little sand is strewed upon each part, which fuses and spreads something like a varnish, and partially defends them from the air; the heat is proper when, notwithstanding the sand, the iron begins to burn away with vivid sparks. The two men then take each one piece, strike them forcibly across the anvil to remove any loose cinders, place them in their true positions, exactly as in Fig. 1792, and two or three blows of the small hammer of the principal or fireman stick them together; the assistant then quickly joins in with the sledge-hammer, and the smoothing off and completion of the work are soon accomplished.

It is of course necessary to perform the work with rapidity, and literally "to strike whilst the iron is hot;" the smith afterwards jumps the end of the rod upon the anvil, or strikes it endways with the hammer; this proves the soundness of the joint, but it is mostly done to enlarge the part, should it during the process have become accidentally reduced below the general size. The sand appears to be quite essential to the process of welding, as although the heat might be arrived at without its agency, the surfaces of the metal would become foul and covered with oxide when unprotected from the air; at all events common experience shows that it is always required. The scarf joint, shown in Figs. 1792 and 1793, is commonly used for all straight bars, whether flat, square, or round, when of medium size.

In very heavy works the welding is principally accomplished within the fire: the two parts are previously prepared either to the form of the *tongue* or *split* joint, Fig. 1794, or to that of the *butt* joint, Fig. 1795, and placed in their relative positions in a large hollow fire. When the two parts are at the proper heat, they are jumped together endways, which is greatly facilitated by their suspension from the crane, and they are afterwards struck on the ends with sledge-hammers, a heavy mass being in some cases held against the opposite extremity to sustain the blows; the heat is kept up, and the work is ultimately withdrawn from the fire, and finished upon the anvil.

The butt joint, Fig. 1794, is materially strengthened, when, as it is usually the case for the paddle shafts of steam-vessels and similar works, the joint whilst still large is notched in on three or four sides, and pieces called *stick-in* pieces, *dowels*, or *charlins*, one of which is represented by the dotted lines, are prepared at another fire, and laid in the notches; the whole, when raised to the welding heat, is well worked together and reduced to the intended size; this mingles all the parts in a very substantial manner. For the majority of works, however, the scarf joint, Fig. 1792, is used, but the stick-in pieces are also occasionally employed, especially when any accidental deficiency of iron is to be feared.

When two bars are required to form a **T** joint, the transverse piece is *thinned down* as at *a*, in Fig. 1796; for an angle or corner the form of *b* may be adopted; but *c*, in which each part is cut off obliquely, is to be preferred. The pieces *a*, *b*, *c*, are represented upside down, in order that the ridges set down on their lower surfaces may be seen. In most cases when two separate bars are to be joined, whatever the nature of the joint, the metal should be first upset, and then set down in ridges on the edge of the anvil, or with a set-hammer, as the plain chamfered or sloping surfaces are apt to slide asunder when struck with the hammer, and prevent the union. When a **T** joint is made of square or thick iron, the one piece is upset, and moulded with the fuller much in the form of the letter; it is then welded against the flat side of the bar: such works are sometimes welded with dowel or tenon joints, but all the varieties of method cannot be noticed.

Fig. 1787 may be taken as an example, in which the parts have no disposition to separate; in this and similar cases the smith often leaves the parts slightly open, in order that the very last process before welding may be the striking the whole edgeways upon the anvil, to drive out any loose scales, cinders, or sand, situated between the joints.

In works that have accidentally broken in the welded part, the fracture will be frequently seen to have arisen from some dirty matter having been allowed to remain between them, on which account, *shuts* or welded joints extending over a large surface are often less secure than those of smaller area, from the greater risk of their becoming foul. In fact, throwing a little small coal between the contiguous surfaces of work not intended to be united, is a common and sometimes a highly essential precaution to prevent them from becoming welded.

The conical sockets of socket chisels, garden spuds, and a variety of agricultural implements, are formed out of a bar of flat iron, which is spread out sideways or to an angle, with the pane of the hammer, and then bent within a semicircular bottom tool also, by the pane of the hammer, to the form of Fig. 1797; after which the sockets are still more curled up by blows on the edges and are perfected upon a taper-pointed mandrel, so that the two edges slightly overlap at the mouth of the socket, and meet pretty uniformly elsewhere, as in Fig. 1798; and lastly, about an inch or more at the end is welded. Sometimes the welding is continued throughout the length, but more commonly only a small portion of the extremity is thus joined, and the remainder of the edges are drawn together with the pane of the hammer.

1798. 1797.

In making wrought-iron hinges, two short slits are cut lengthways and nearly through the bar, towards its extremity; the iron is then folded round a mandrel, set down close in the corner, and the two ends are welded together. To complete the hinge, it only remains to cut away transversely, either the central piece or the two external pieces to form the knuckles, and the addition of the pin or pivot finishes the work.

Musket-barrels, when made entirely by hand, were forged in the form of long strips about a yard long and four inches wide, but taper both in length and width, which were bent round a cylindrical mandrel until their edges slightly overlapped; they were then welded at three or four heats, by introducing the mandrel within them instantly on their removal from the fire at the proper heat, in order to prevent the sides of the tube from being pressed together by the blows of the hammer.

They have been subsequently, and are now almost universally welded by machinery at one heat, and whilst of the length of only one foot, as on removal from the fire the mandrel is quickly introduced, and the two are passed through a pair of grooved rollers: they are afterwards extended to the full length by similar means, but at a lower temperature, so that the iron is not so much injured as when thrice heated to the welding point.

The twisted barrels are made out of long ribands of iron wound spirally around a mandrel, and welded on their edges by jumping them upon the ground, or rather on an anvil embedded therein. The plain stub barrels are made in this manner, from iron manufactured from a bundle of stub-nails, welded together and drawn out into ribands to ensure the possession of a material most thoroughly and intimately worked. The Damascus barrels are made from a mixture of stub-nails and clippings of steel in given proportions, puddled together, made into a bloom, and subsequently passed through all the stages of the manufacture of iron already explained, to obtain an iron that shall be of unequal quality and hardness, and therefore display different colors and markings when oxidized or browned.

Other twisted barrels are made in the like manner, except that the bars to form the ribands are twisted whilst red-hot like ropes, some to the right, others to the left, and which are sometimes again laminated together for greater diversity; they are subsequently again drawn into the ribands and wound upon the mandrel, and frequently two or three differently prepared pieces are placed side by side to form the complex and ornamental figures for the barrels of fowling-pieces, described as "*stub-twist, wire-twist, Damascus twist,*" &c., which processes are minutely explained and figured by Greener, "on Gunnery."

All these matters are also explained in Wilkinson's "Engines of War," which likewise treats of one

method amongst others of the formation of the Damascus gun-barrels, by arranging twenty-five thin bars of iron and mild steel in alternate layers, welding the whole together, drawing it down small, twisting it like a rope, and again welding three such ropes, for the formation of the riband, which is then spirally twisted to form a barrel, that exhibits, when finished and acted upon by acids, a diversified laminated structure, resembling when properly managed an ostrich feather.

To turn from these engines of destruction to a modification of one of them to a happier purpose. When the illumination by gas was first introduced in the large way, by Aaron Manby, Esq., then of the Horsley Iron Works, the old musket-barrels, laid by in quiet retirement from the fatigues of the last war, were employed for the conveyance of gas; and by a curious coincidence, various iron foundries desisted in a great measure from the manufacture of iron ordnance, and took up the peaceful employment of casting pipes for gas and water.

The breech ends of the musket-barrels were broached and tapped, and the muzzles were screwed externally, to connect the two without detached sockets. From the rapid increase of gas illumination, the old gun-barrels soon became scarce, and new tubes with detached sockets, made by the old barrel-forgers, were first resorted to. This led to a series of valuable contrivances for the manufacture of the wrought-iron tubes, commencing with Russel's patent, in 1824, under which the tubes were first bent up by hand-hammers and swages, to bring the edges near together; and they were welded between semicircular swages, fixed respectively in the anvil, and the face of a small tilt-hammer worked by machinery, by a series of blows along the tube, either with or without a mandrel. The tube was completed on being passed between rollers with half-round grooves, which forced it over a conical or egg-shaped piece at the end of a long bar, to perfect the interior surface.

Various steps of improvement have been since made; for instance, the skelps were bent at two squeezes, first to the semi-cylindrical, and then to the tubular form, (preparatory to welding,) between a swage-tool five feet long, worked by machinery. The whole process was afterwards carried on by rollers, but abandoned on account of the unequal velocity at which the greatest and least diameters of the rollers travelled.

In the present method of manufacturing the patent welded tube, the end of the skelp is bent to the circular form, its entire length is raised to the welding heat in an appropriate furnace, and as it leaves the furnace almost at the point of fusion, it is dragged by the chain of a draw-bench, after the manner of wire, through a pair of tongs with two bell-mouthed jaws; these are opened at the moment of introducing the end of the skelp, which is welded without the agency of a mandrel.

By this ingenious arrangement, wrought-iron tubes may be made from the diameter of six inches internally and about one-eighth to three-eighths of an inch thick, to as small as one-quarter inch diameter and one-tenth bore; and so admirably is the joining effected in those of the best description, that they will withstand the greatest pressures of gas, steam, or water, to which they have been subjected, and they admit of being bent both in the heated and cold state almost with impunity. Sometimes the tubes are made one upon the other when greater thickness is required; but these stout pipes, and those larger than three inches, are comparatively but little used.*

Various articles with large apertures are made, not by punching or cutting out the holes, but by folding the metal around the beak-iron, and finishing them upon a triblet of the appropriate figure; thus the complete smithy is generally furnished with a series of cones turned in the lathe, for making rings, the ends of which are folded together and welded, such as Fig. 1799. The same rings, when made of such cast-steel as does not admit of being welded, are first punched with a small hole, and gradually thinned out by blows around the margin, until they reach the diameter sought; but this, like numerous other works, requires considerable forethought to proportion the quantity of the material to its ultimate form and bulk, so that the work may not in the end become either too slight or too heavy.

Chains may be taken as another familiar example of welding; in these the iron is cut off with a plain chamfer, as from the annular form of the links their extremities cannot slide asunder when struck; every succeeding link is bent, introduced, and finally welded. In some of these welded chains the links are no more than half an inch long, and the iron wire one-eighth of an inch diameter; several inches of such chain are required to weigh one pound; these are made with great dexterity by a man and a boy at a small fire. The curbed chains are welded in the ordinary form and twisted afterwards, a few links being made red-hot at a time for the purpose.

The massive cable-chains are made much in the same manner, although partly by aid of machinery. The bar of iron, now one, one and a half, or even two inches diameter, is heated, and the scarf is made as a plain chamfer by a cutting machine; the link is then formed by inserting the end of the heated bar within a loop in the edge of an oval disk, which may be compared to a chuck fixed on the end of a lathe mandrel. The disk is put in geer with the steam-engine; it makes exactly one revolution, and throws itself out of motion; this bends the heated extremity of the iron into an oval figure: afterwards it is detached from the rod with a chamfered cut by the cutting machine, which at one stroke makes the second scarf of the detached link, and the first of that next to be curled up.

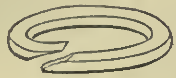
The link is now threaded to the extremity of the chain, closed together, and transferred to the fire, the loose end being carried by a traverse crane; when the link is at the proper heat, it is returned to the anvil, welded, and dressed off between top and bottom tools, after which the cast-iron transverse stay is inserted, and the link having been closed upon the stay, the routine is recommenced. The work

* A piece of tube of the smallest dimensions, and fourteen feet long, which has been bent cold almost into the form of the Gordian knot, may be seen at the Institution of Civil Engineers. The wrought-iron tubes of hydrostatic presses, which measure about half an inch internally, and one-fourth to three-eighths of an inch thick in the metal, are frequently subjected to a pressure equal to *four tons* on each square inch. Pipes proved to the same degree are also used in Mr. Perkins' patent apparatus for warming buildings, and in his recently patented steam-boiler. The safety of each of these is entirely secured by a fusible plug, which melts and allows the water to escape into the fire when its temperature exceeds any predetermined degree, namely, from about 300° to 600° F., generally the former.

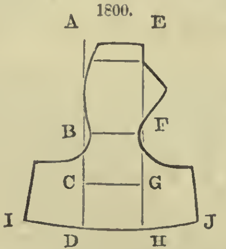
commonly requires three men, and the scarf is placed at the side of the oval link, and flatway through the same. In similar chains made by hand it is, perhaps, more customary to weld the link at the *crown*, or small end.*

The succeeding illustration of the practice of forging will be that of the formation of a hatchet, Figs. 1800 and 1801, which, like many similar tools, is made by doubling the iron around a mandrel, to form the *eye* of the tool; it will also permit the description of some other general proceedings, and likewise the introduction of the steel for the cutting edge.

1799.



1800.



1801.

1802.

1803.

In making the hatchet, a piece of flat iron is selected, of the width of A E, and twice the length of A D; it is thinned and extended sideways before it is folded together, to form the projections near B and F, by blows with the pane of the hammer or a round-edged fuller, on the lines A B to E F, but the metal must be preserved of the full thickness at the part A E, to form the poll of the hatchet, although a piece of steel is frequently welded on at that part as a previous step. The work is then bent round a mandrel, Figs. 1802 and 1803, exactly of the section of the eye as seen in Fig. 1801, and the work is welded across the line B F; the mandrel is again introduced, and the eye is perfected.

A slip of shear-steel, equal in length to D H, is next inserted between the two tails of the iron, as yet of their original size, up to the former weld, and all three are welded together between C G D H: the combined iron and steel are now drawn out sideways, by blows of the pane of the hammer on and between C D and G H, to extend them together to I J. The tool is then flattened and smoothed with the face of the hammer, and the edges are pared with straight or circular chisels to the particular pattern, and trimmed with a round-faced hammer, or a top fuller.

In smoothing off the work, the smith pursues his common method of first removing with a file the hard black scales that appear like spots when the work is removed from the fire; he then dips the hammer in the slake trough, and lets fall upon the anvil a few drops of the water it picks up, the explosion of which, when the red-hot metal is struck upon it, makes a smart report and detaches the scales that would be otherwise indented in the work. It should be observed that the mandrel, Fig. 1802, is purposely made very taper, and is introduced into the hole from both sides, so that the eye may be smaller in the middle; when, therefore, the handle of the tool is carefully fitted and wedged in, the handle is, as it were, dovetailed, and the tool can neither fly off nor slip down the handle; the same mode is also adopted for the heads of hammers.

In spades, and many similar implements, the steel is introduced between the two pieces of iron of which the tools are made; in others, as plane irons and socket chisels, it is laid on the outside, and the two are afterwards extended in length or width to the required size. The ordinary chisel for the smith's shop is made by inserting the steel in a cleft, as in Fig. 1794, and so is also the *pane* of a hammer; but the flat *face* of the hammer is sometimes stuck on whilst it continues at the extremity of a flat bar of steel; it is then cut off, and the welding is afterwards completed. At other times the face of the hammer is prepared like a nail, with a small spike and a very large head, so as to be driven into the iron to retain its position, until finally secured by the operation of welding.

In putting a piece of steel into the end of an iron rod to serve for a centre, the bar is heated, fixed horizontally in the vice, and punched lengthways with a sharp square punch, for the reception of the steel, which is drawn down like a taper tang or thick nail, and driven in; the whole is then returned to the fire, and when at the proper heat united by welding, the blows being first directed as for forming a very obtuse cone, to prevent the piece of steel from dropping out.

For some few purposes the blistered steel is used for welding, either to itself or to iron. It is true the first working under the hammer in a measure changes it to the condition of shear-steel, but less efficiently so than when the ordinary course of manufacture is pursued, as the hammering is found to improve steel in a remarkable and increasing degree.

* The tires of wrought-iron wheels for locomotive engines and carriages, are in general bent to the circle by somewhat analogous means to those employed in chain-making, as are likewise the skelps for the twisted barrels of guns: the latter only require a mandrel or spindle with a winch handle at the one extremity, and a loop for the end of the skelp, which is wound in contact with the mandrel by means of a fixed bar placed near the same; such barrels are coiled up in three lengths, which are joined together after the spirals are welded.

Wheels for railways display many curious examples of smithing: thus some, except the nave, are made entirely by welding; others are partly combined with rivets; in all, the nave or boss is a mass of cast-iron usually poured around the ends of the spokes, with the exception of Bourne and Bartley's patent wheel, in which the nave, spokes, and periphery, are made entirely of wrought-iron and welded together.

The common practice of welding the tires of railway wheels is now as follows: the tires are cut off with ridges in the centre, so as in meeting to form two angular notches, into which two thin iron wedges are subsequently welded radially; the four parts thus united together in the form of a cross, make a very secure joint without the necessity for upsetting the iron, which would distort the form of the tire.

For the majority of works in which it is necessary to weld steel to iron, or steel to steel, the shear, or double shear, is exceedingly suitable; it is used for welding upon various cutting tools, as the majority of the cast-steel will not endure the heat without crumbling under the hammer. Shear-steel is also used for various kinds of springs, and for some cutting tools requiring much elasticity.

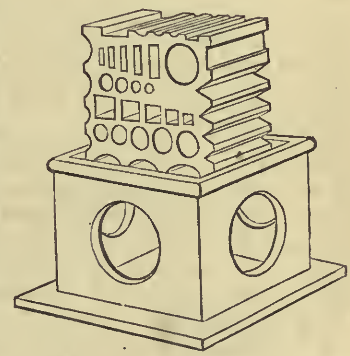
It is more usual to reserve the cast-steel for those works in which the process of welding is not required, although of late years mild cast-steel, or welding cast-steel, containing a smaller proportion of carbon has been rather extensively used; but in general the harder the steel the less easily will it admit of welding, and not unfrequently it is altogether inadmissible.

The hard or *harsh* varieties of cast-steel are somewhat more manageable when fused borax is used as a defence instead of sand, either sprinkled on in powder or rubbed on in a lump; and cast-steel, otherwise intractable, may be sometimes welded to iron by first heating the iron pretty smartly, then placing the cold steel beside it in the fire, and welding them the moment the steel has acquired its maximum temperature, by which time the iron will be fully up to the welding heat. When both are put into the fire cold alike, the steel is often spoiled before the iron is nearly hot enough, and therefore it is generally usual to heat the iron and steel separately, and only to place them in contact towards the conclusion of the period of getting up the heat. In forging works either of iron or steel, the *uniformity* of the hammering tends greatly to increase and equalize the strength of each material; and in steel, judicious and equal forging greatly lessens also the after-risk in hardening.*

Concluding remarks on forging; and the applications of heading tools, swage tools, punches, &c.— With the utmost care and unlimited space, it would have been quite impossible to have conveyed the instructions called for, in forging the thousand varieties of tools and parts of mechanism the smith is continually called upon to produce; and all that could be reasonably attempted in this place, was to convey a few of the general features and practices of this most useful and interesting branch of industry. It is hoped that such combinations of these methods may be readily arrived at as will serve for the majority of ordinary wants.

The smith in all cases selects or prepares that particular form and magnitude of iron, and also adopts that order of proceeding which experience points out as being the most exact, sound, and economical. In this he is assisted by a large assortment of various tools and moulds for such parts of the work as are often repeated, or that are of a character sufficiently general to warrant the outlay, and to some of which I will advert.

1804.



The heading tools, Figs. 1777 and 1778, are made of all sizes and varieties of forms; some with a square recess to produce a square beneath the head, to prevent the bolt from being turned round in the act of tightening its nut; others for countersunk and round-headed bolts, with and without square shoulders: many similar heading tools are used for all those parts of work which at all resemble bolts, in having any sudden enlargement from the stem or shaft. The holes in the swage-block, Fig. 1790, are used after the manner of heading tools for large objects; the grooves and recesses around its margin, also serve in a variety of works as bottom swages beyond the size of those fitted to the anvil. At the opposite extreme of the heading tools, as to size, may be noticed those constantly employed in producing the smallest kinds of nails, brads, and rivets, of various denominations; some of which heading tools divide in two parts like a pair of spring forceps, to release the nails after they have been forged.† These kinds are called *wrought*-nails and brads, in contradistinction to similar nails cut out of sheet-iron by various processes of shearing and punching, which latter kinds are known as *cut-brads* and nails.

The top and bottom rounding tools, Fig. 1774, are made of all diameters for plain cylindrical works; and when they are used for objects the different parts of which are of various diameters, it requires much care to apply them equally on all parts of the work, that the several circles may be concentric and true one with the other, or possess one axis in common. To ensure this condition some of these rounding tools are made of various and specific forms, for the heads of screws, for collars, flanges, or enlargements, which are of continual occurrence in machinery; for the ornamental swells or flanges about the iron work of carriages, and other works. Such tools, like the pair represented in Figs. 1805 and 1806, are called swage or collar tools; they save labor in a most important degree, and are thus made. A solid mould, core, or striker, exactly a copy of the work to be produced, is made of steel by hand-forging, and then turned in the lathe to the required form, as shown in Fig. 1807.

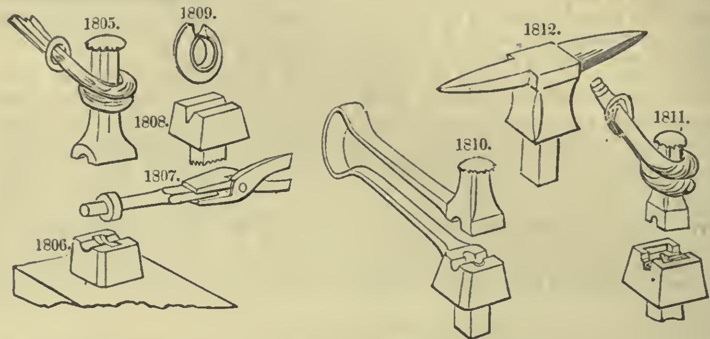
* When cast-steel has been spoiled by overheating, it may be partially recovered by four or five reheatings and quenchings in water, each carried to an extent a little less and less than the first excess; and lastly, the steel must have a good hammering at the ordinary red heat. Some go so far as to prefer for cutting tools the steel thus recovered, but this seems a most questionable policy, although the change wrought by this treatment is really remarkable; as the fragment broken off from the bar in the spoiled state, and another from the same bar after part restoration and hardening, will exhibit the extreme characters of coarse and fine.

The hammering we suspect to be the principal requisite, and in superior tools it should be continued until the work is nearly cold, to produce the maximum amount of condensation before hardening; but no hammering will restore the loss of tenacity consequent upon the overheating, or even the too frequent heating, of steel, without excess.

† The forge used by the nail-makers is built as a circular pedestal, with the fire in the centre and the chimney directly over it; the rock-staff of the bellows extends entirely around the forge, so that one of the four or five persons who work at the same fire is continually blowing it, whence the fire is always at the heat proper for welding, and which keeps the nails sound and good.

The top tool is first moulded to the general form in an appropriate aperture in the swage-block, Fig. 1804; it is faced with steel like a hammer, and the core, Fig. 1807, is indented into it; the blows of the sledge-hammer not being given directly upon the core, but upon some hollow tool previously made; otherwise the core must be filed partly flat to present a plane surface to the hammer. The bottom tool, which is fitted to the anvil, is made in a similar manner, and sometimes the two are finished at the same time whilst hot, with the cold striker between them; their edges are carefully rounded with a file so as not to cut the work, and lastly they are hardened under a stream of water.

In preparing the work for the collar tools, when the projection is inconsiderable, the work is always drawn down rudely to the form between the top and bottom fullers, as in Fig. 1772; but for greater economy, large works in iron are sometimes made by folding a ring around them, as in Fig. 1780. The metal for a large ring is occasionally moulded in a bottom tool, like Fig. 1808, and coiled up to the shape of Fig. 1809, after which it is closed upon the central rod between the swages, and then welded within them. The tools are slightly greased, to prevent the work from hanging to them, and from the same motive their surfaces are not made quite flat or perpendicular, but slightly conical, and all the angles are obliterated and rounded.



The spring swage tool, represented in Fig. 1810, is used for some small manufacturing purposes; it differs in no respect from the former, except in the steel spring which connects the two parts; it is employed for light single hand-forgings. Other workmen use swage tools, such as Fig. 1811, in which there is a square recess in the bottom tool to fit the margin of the top tool so as to guide it exactly to its true position;* this kind also may be used for single hand works, and is particularly suited to those which are of rectangular section, as the shoulders of table-knives: these do not admit of being twisted round, which movement furnishes the guide for the position of the top tool in forging circular works.

The smith has likewise a variety of punches of all shapes and sizes, for making holes of corresponding forms; and also drifts or mandrels, used alone for finishing them, many of which, like the turned cones, are made from a small to a large size to serve for objects of various sizes. Two examples of the very dexterous use of punches are in the hands of almost every person, namely, ordinary scissors and pliers.

The first are made from a small bar of flat steel; the end is flattened and punched with a small round hole, which is gradually opened upon a beak-iron, Fig. 1812, attached to the square hole of the anvil; the beak-iron has a shallow groove (accidentally omitted) for rounding the inside of the bows. The remaining parts of the scissors are moulded jointly by the hammer and bottom swage tools; but the bows are mostly finished by the eye alone.

In the Lancashire pliers, the central half of the joint is first made; the aperture in the other part is then punched through sideways, and sufficiently bulged out to allow the middle joint to be passed through, after which the outsides are closed upon the centre. This proceeding exhibits, in the smallest kinds especially, a surprising degree of dexterity and dispatch, only to be arrived at by very great practice; and which in this and numerous other instances of manufacture could be scarcely attained but for the enormous demand, which enables a great subdivision of labor to be successfully applied to their production.† ‡

FORGING MACHINE, Ryder's Patent. Fig. 1813 is a front view, and fig. 1814 an end view of the machine; fig. 1815 is a section across the swages, and the apparatus connected with their motion. The machine consists of a strong cast-iron frame, carrying the driving-shaft *a*. On this shaft are forged eccentrics, which give motion to the upper swage-holders, *b b*. These swage-holders are guided vertically by the frame, whilst the motion required by the eccentric is allowed for by the pieces *c c*, the toes of which work in the hollow on the top of the swage-holder. Each upper swage-holder is provided with a spiral spring, shown in fig. 1815, which bears on a key fixed in the frame, and raises the swage after the eccentric has depressed it. A slot is cut in the swage-holder to allow it to slide on the key.

Machines of this class are always liable to breakage from a bar of too large a size being put between the swages. This can only be remedied by allowing some elasticity, which in this case is ingeniously effected in the following manner. A space *e*, in the lower swage-holder, is filled with cork, which can be compressed by the screw *f* to any degree of hardness. The screw *g*, which passes through the nut *h*, let into the framing, serves to raise the lower swage bodily, when it is required to vary the size of

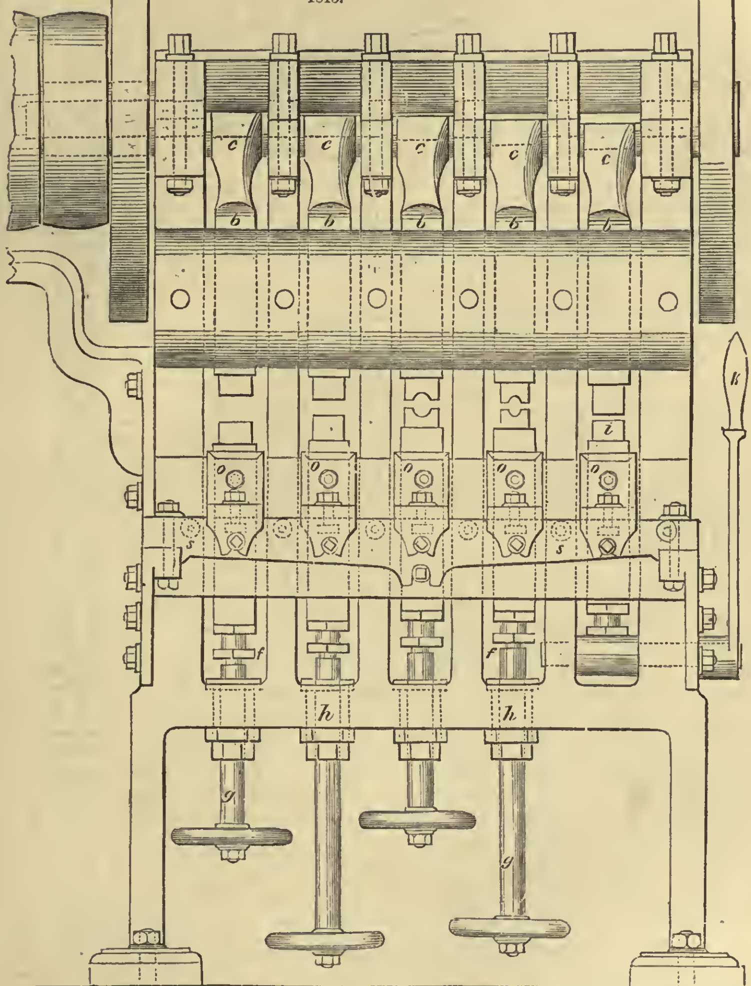
* In practice the recess in the bottom tool would be deeper, and taper or larger above to guide the tool more easily to its place; but if so drawn the figure would have been less distinct.

† The remarks on steel also refer to the necessity of good primary forging and hammering to produce homogeneity and also to many of the other points generally admitted by practical men as being conducive to the success of hardening.

‡ Holtzapfel's Turning and Mechanical Manipulation.

the work to be executed. The tool *i* forms a pair of shears to finish the work to a proper length, by moving the handle *k*, which acting on an eccentric, raises the lower tool to meet the upper one. This arrangement is necessary, as, from the rapid motion of the tools, which make 600 to 700 blows per minute, it would be impossible to introduce the work without bruising it. *o o o o* are a series of rests, one being opposite to each pair of tools, which can be adjusted both in height and horizontal distance by

1813.



means of the screws *n r*, the table *s s*, carrying the rests, can also be moved along the frame to facilitate the adjustment. In using the machine, the swages are adjusted so that by placing the rod of iron successively between them, it is drawn down to the size required, whilst the length of each part is accurately determined by placing the end of the rod in the rest. The machine cannot thus turn out the work too small, whilst, at the same time, it is so near the finished size, that very little has to be taken off in the lathe.

This machine, which was exhibited in action at the Meeting of the British Association at Manchester, is quite portable, occupying a space of 3 feet by 4 feet. It promises to be of particular use in forging such works as cotton spindles and others required in great numbers, as the diameters and lengths of their respective parts can be determined with the same accuracy as that of objects moulded in sand and cast in the ordinary way; and the forgings require but little adjustment beyond centering, to adapt them to the turning lathe.

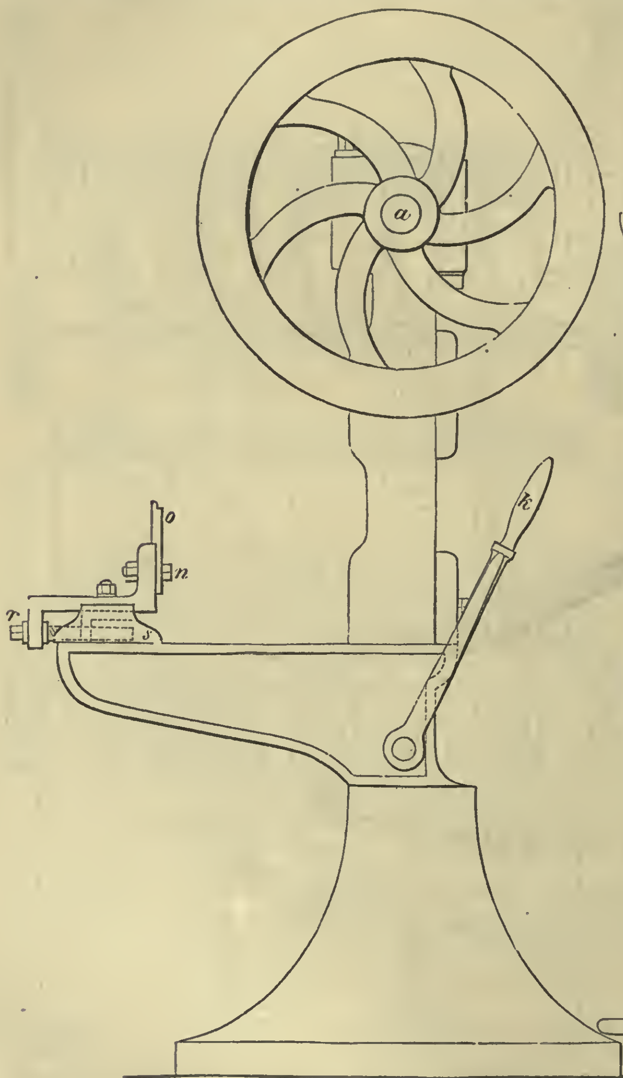
For other forging machines, see HAMMER.

FORK. In machinery, a short piece of steel which fits into one of the sockets or chucks of a lathe,

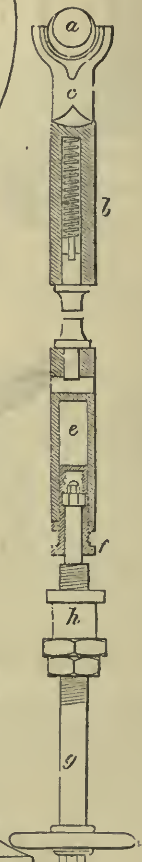
and is used by wood turners for carrying round the piece to be turned; it is flattened at the end, like a chisel, but has a projecting centre point, to prevent the wood from moving laterally.

FORMULÆ. Characters or symbols, by which certain rules or quantities in mathematics are represented; or in chemistry, by which substances, either simple or compound, are known.

1814.

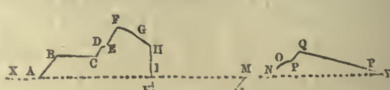


1815.



FORTIFICATION is the art of constructing such works of defence as may enable a comparatively small number of men to maintain possession of a city or place against the assaults of a superior force

Modern fortification, though differing in some subordinate details, which differences are dignified by the name of *systems*, closely resemble one another in all their essential parts. In order to explain their structure, it will be convenient to consider them first without reference to their form, or the position of the ground lines in respect to each other, but merely as defences against an army with artillery advancing directly in front. The annexed figure represents a vertical section of a regular fortification on the ground line X Y, the place to be defended being supposed between X and A. The mass of earth A B C D E F G H forms the rampart with its parapet. A B is the interior slope of the rampart; B C is the *terre-plein* of the rampart, having a breadth of about 40 feet, on which the troops and cannon are placed; D E is called the *banquette*, or step, on which the soldiers mount to fire over the parapet; E F G is the

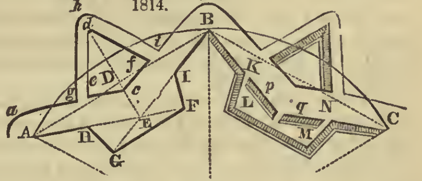


parapet, of a height (about 7 feet) sufficient to protect the men and guns on the terre-plein, and sloped in the direction F G towards M, the opposite edge of the ditch, so that a man approaching there may be seen and fired at; G H is the exterior slope of the parapet; H I is the *revetment*, or wall of masonry supporting the rampart, and strengthened by buttresses placed at small intervals behind it. This must be of sufficient height to prevent its being easily scaled; but yet must not rise higher than the edge of the exterior work at Q, in order that it may not be seen and breached by distant batteries. The exterior front of the rampart, covered with the revetment H K, is called the *escarp;* I K L M is the ditch, the dimensions of which will be determined by the nature of the ground, but must be such, in general, that its excavation or *deblai* must produce sufficient earth or *remblai* to form the rampart; the opposite side of the ditch L M is the *counterscarp*, also supported by a revetment of masonry; M N is the *covered way*, a space about 10 yards in breadth, having a *banquette* N O P, and protected by a parapet P Q, the superior slope of which, Q R, is called the *glacis*. The use of the covered way is to allow troops to be drawn up, unseen by the besiegers, for the purpose of making sorties; it also enables the garrison to keep up a closer fire on the approaches of the enemy, and its parapet forms a strong protection to the revetment of the rampart.

It is easy to see that the strength of a place will be increased by a succession of such works, so that when the besieged are driven from one they may retire to the next behind it. Sometimes there are three ditches with intermediate works, or rather works raised within the ditch itself, similar to the rampart, though of a less height, in order that the guns on the rampart may range above them. A work of this sort, between the inner and the main ditch, is called a *tenaille;* that between the main ditch and the outer ditch is called a *ravelin*. All works outside the ditch are called *outworks*.

Before proceeding to construct a fortification, it is necessary to lay down a *plan*. This will differ in some respects according to the system adopted; but the following description, which properly belongs to Vauban's First System, will explain the general method: When the work is regular, the sides are all equal, and therefore the general form will be that of a polygon inscribed in a circle. The first thing to be done is to determine on the number of sides. We shall suppose them to be six, and the radius of the circumscribing circle to be 360 yards, when the construction will be as follows: Let A B, B C be two sides of a hexagon inscribed in a circle; each of these lines will be equal to the radius, or 360 yards. Bisect A B in D; draw the perpendicular D E, on which set off D E, equal to one sixth of A B or 60 yards; draw the lines A E F and B E G, in which take A H and B I, each equal to 100 yards, or five ninths of A D; make H F and I G each equal to the distance H I; then the line A H G F I B is the principal outline of the front; and by making the same construction on each of the sides of the hexagon, we obtain the principal outline of the whole fortification, or that by which the first figure of the work is defined.

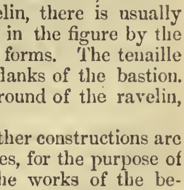
1814.



The part F I B K L is called the *bastion*, B I and B K are the *faces* of the bastion; I F and K L are its *flanks;* F L is the *gorge;* G F is the *curtain;* A F and B G are the *lines of defence;* B is the *flanked angle;* I and K are the *angles of the shoulder;* G F L and M the *angles of the flank*. From the points A and B as centres, and a radius of 40 yards, describe circular arcs; if lines be drawn from the opposite angles of the shoulder H I to touch those arcs, the parts of those lines *a c*, *b c*, together with the arcs, will represent the *counterscarp* of the ditch. The curtain is defended by a *ravelin*, which is constructed thus: From *c*, the re-entering angle of the counterscarp, set off, on the perpendicular D E, a line *c d*, equal to 110 yards, and from *d* draw *d e*, *d f*, in the directions of H and I, to meet the counterscarp; then *d e* and *d f* are the *faces* of the ravelin, and *c e* and *c f* its *semi-gorges*. The counterscarp *g h i* of the ditch of the ravelin is parallel to its faces, and rounded off at *h*. Stairs, called *pas-de-souris*, are constructed to facilitate the descent from the ravelin to the ditch. Besides the ravelin, there is usually another appendage to the bastion and curtain. This is the *tenaille*, represented in the figure by the parts *p q* made in the direction of the lines of defence; but it has sometimes other forms. The tenaille is made in the ditch before the curtain, with passages between the ends and the flanks of the bastion. It is a low work, having its parapet only about three feet higher than the level ground of the ravelin, and its use is to defend the bottom of the ditch by a grazing fire.

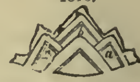
Such are the works which form the envelop of the place fortified; but various other constructions are in most cases added, according to the nature of the ground and other circumstances, for the purpose of protecting or strengthening such parts as are most exposed, or of interrupting the works of the besiegers. These additional constructions are either internal or external. Among the former are *retrenchments* of various kinds, either constructed at the same time with the principal works or thrown up during the siege. They are made behind the ramparts, or the bastions most exposed to attack, their use being to enable the garrison to continue the defence from behind a fresh obstacle when a rampart or bastion has been breached. When a hill or rising ground overlooks any of the works, a *cavalier* is raised, about ten or twelve feet higher than the rest of the works. This is commonly placed within the bastion when it has the same form, but sometimes on the middle of the curtain when its form is semicircular. Of the exterior works one of the most important is the *counterguard*, constructed to cover some of the principal parts, as the bastion or the cavalier, in such a manner that without obstructing their fire it prevents them from being breached till itself is taken. The counterguard is constructed parallel with the faces of the work it is destined to cover; and it must be lower than the principal work, though of a sufficient height to screen its revetment. A *hornwork*, represented in the annexed figure, is composed of two branches, and a front composed of two half bastions and a curtain, resembling a front of the body of

1815.



the place. It is here represented as made before the curtain, but it may be also constructed before a bastion. A *crown-work* is of the same nature as a horn-work, but larger, and having two fronts, which give it somewhat the appearance of a crown. Horn-works and crown-works are constructed where a large spot of ground lies beyond the fortification which might be advantageous to an enemy, or to cover a gate or entrance into a town. *Lunettes, a a,* are placed on both sides of the ravelin, and are constructed on lines bisecting the faces of the ravelin at right angles. A *bonnet, b,* is a work covering the salient angle of the ravelin. *Tenaillons* are similar in construction to lunettes, but having one of their faces formed on lines which are the production of the faces of the ravelin, instead of bisecting those faces. The application of all these and other works of a similar description depends on the nature of the localities; and it must be left to the judgment of the engineer to determine in each particular case which is best adapted to the ground.

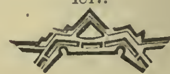
1816.



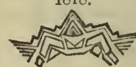
We have already alluded to the use and importance of the covered way. In order to increase its strength *traverses,* or portions of parapet, are thrown across it, which screen it from an enfilading fire, and enable the defenders to dispute its possession foot by foot. *Places of arms,* or places for assembling troops, and protected by traverses and *redoubts,* are also formed on it at the re-entering and salient angles of the counterscarp. The redoubts serve not only as a place of retreat, but facilitate the making of sorties upon the enemy's lodgments.

The descriptions given above belong more especially to that method of fortification which, in the military schools, is denominated Vauban's first system. In his second system, represented in the annexed figure, he separated the bastions from the body of the place by a ditch about 40 feet wide, in order that the besieger, after the breach and capture of the bastions, might be compelled to renew his operations against his *enceinte* or body of the place. The angles of the polygon are crowned by pentagonal towers of masonry, called *tower bastions,* to which, in fact, the regular bastions only form countergards. Vauban's third system does not differ in any material respect from the second. He increased the size of the ravelin, and gave it a redoubt. The tower bastions were likewise made larger, and the curtain which united them was broken inwards, so as to form two small flanks underneath; while casements for cannon were constructed, to co-operate with those of the tower bastions in the defence of the ditch.

1817.



1818.



Coehorn's system.—Contemporary with Vauban was the Baron de Coehorn, director-general of the fortifications of the United Provinces of Holland. This celebrated engineer is also the author of three different systems, though the third has never been constructed. His methods are only applicable in low swampy countries, like Holland; and the object which he kept principally in view was to throw such obstacles in the way of a besieging force that the place could only be approached with great difficulty and hazard. This he sought to accomplish by covering and flanking his works more effectually than had previously been done, and by depriving the assailant of the room necessary for erecting his batteries. An idea of his methods may be formed from the annexed figure, which represents his first system. It is constructed on a hexagon; the second was on a heptagon, and the third on an octagon. And it may be remarked of his systems in general, that they differ from Vauban's principally in the greater width of the ditch and the narrow space between the flanks.

1819.

Cormontaigne's system.—The methods of Vauban were improved in many essential respects by Cormontaigne. In his system, which is here represented, the faces of the bastion are made longer than in Vauban's methods, and the flanks are placed at right angles with the faces of the opposite bastions. The enlargement of the bastion renders it capable of containing interior retrenchments; and the flanks, though shortened, are better covered. His ravelins are also constructed on a larger base, and contain a larger redoubt, from which the besiegers can keep up a reverse fire on breaches made in the collateral bastions; so that the assault upon the latter becomes impracticable until the ravelin and its redoubt are both captured. The combination round the extremities of the traverses of the covered way are arranged in a zigzag line; so that the passage round the extremity of one traverse is defended by the fire of another in its rear, and the advance of the assailants along the covered way thereby checked. In general, Cormontaigne's system possesses greater defensive properties, and is more economical of materials.

1820.

Modern System.—Fig. 1821 represents what is called the modern system: it varies but little from that of Cormontaigne. The ravelin is made to cover the shoulder of the bastion more effectually by a greater projection, and its faces are retrenched by *coupures* or cuts through the rampart, perpendicular to the faces of the bastion, which prevent the enemy from taking the redoubt in the re-entering place of arms without first possessing himself of the redoubt in the ravelin.

1821.

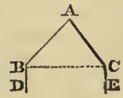
All the systems above enumerated agree in their principal features, and may be included under the name of the bastion system. Some engineers, however, have pointed out defects which appear to be inherent in the system, and proposed to give the polygon a different form. By suppressing the curtain and the tenaille, and producing the faces of the bastions inward, a line of rampart would be formed presenting simply a succession of salient and re-entering angles. But as the

plan has never been practically carried into effect, it is unnecessary to enter into particulars. In the present state of the military art, such is the superiority of the means of attack over those of defence, that however strong the works may be, and however skilfully disposed, their reduction, when assailed by adequate means, is, generally speaking, a matter of absolute certainty. The besieging army, sheltered by its trenches from the missiles of the garrison, advances in zigzag lines parallel to the faces of the ramparts, till it passes over or circumvents all the exterior defences of the place, and arrives at the main wall, where a breach has been made by batteries erected for the purpose. To this covered mode of attack, supported by the ricochet batteries, by which the defenders are driven from the ramparts and the guns dismounted, it is perhaps impossible to offer any effectual resistance. Indeed, such is the perfection to which the art of attack has been reduced, that even the length of time which any fortress will be able to hold out against an enemy provided with the proper train of sappers and miners, and the implements necessary for carrying on their operations, may be computed with the greatest precision.

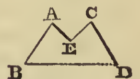
Field fortification.—Field fortification is the art of constructing all kinds of temporary works for assisting the operations of an army in the field, and enabling it to maintain a position against a superior force. On account of the endless varieties and accidents of the ground, the observance of fixed rules is, indeed, impracticable: nevertheless there are certain general maxims which apply to the construction of fortifications of all kinds, whether temporary or permanent. For example, works constructed to flank others, must not be at so great a distance as to be beyond the effective range of musketry: the angles of defence should be nearly right angles, and the salient angles as obtuse as possible. The general nature of defensive works is also the same in all cases, namely, a ditch and a parapet; though, as the pickaxe and the spade are the only implements which an army in the field can carry about with it, the depth and width of the ditch and the height of the parapet are in field-works necessarily limited to what can be effected by these simple means.

Field-works are usually divided into three classes: 1, works open at the gorge; 2, works inclosed all round; and 3, lines either continued or with intervals. To the first class belong *redans*, single and double, *tenailled heads*, and *bastioned heads;* to the second, *redoubts*, *star forts*, and *bastioned forts;* and to the third, lines of various kinds for defending a position. The *redan* is the simplest of all works, consisting merely of two lines, A B and A C, forming an angle with each other. It is only employed for such purposes as defending the avenues of a village, bridge, or defile. The length given it is usually about 50 yards. When the redan is thrown out in front of other works it is called a *fleche*, or arrow. Lunettes are also applied for similar purposes, and are formed by adding two parallel faces, B D and C E, to the redan, at the extremities of its open flanks. The *double redan*, or *bonnet de prêtre*, consists of two faces, A B and C D; and two flanks A E and C E, usually shorter than the faces, and affording a reciprocal defence to each other. The re-entering angle at E should be a right angle; if it is less, the two flanks are in danger of being struck by each other's fire; and if it is much greater than a right angle, the defence will be weakened; for it is found by experience that soldiers placed behind a screen invariably fire straight before them, or at right angles to the screen. When a greater extent of front is to be fortified, the lines are disposed in the form of bastions or tenailles, and thence called *bastioned heads*, and *tenailled heads.*

1822.

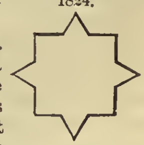


1823.



Redoubts are works closed on all sides, of a polygonal or quadrilateral figure, and usually square. An opening is left in one of the sides, for communication with the exterior, and a traverse is thrown up within for protection. As the work is without flanks, the ditches are left without defence. The angles are sometimes rounded, or cut off, in order that a fire may be maintained on an assailant advancing in the direction of the diagonal.

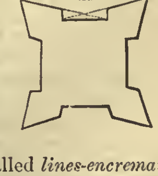
1824.



Star forts are inclosed works constructed upon an equilateral triangle or a square. In the former case they have six points, in the latter eight. When constructed on a square, each of the sides (which may be about 90 yards long) is divided into three equal parts, and on the middle part an equilateral triangle is constructed, which gives the trace of the figure. The object of this work is to remedy the defects of the redoubt by flanking the angles of the square; but as a considerable space is consumed by the re-entering angles, it scarcely admits of sufficient troops and artillery being placed in it for its defence.

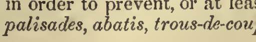
Bastioned forts are constructed in the field on the same principles as in permanent works; but are only constructed on the square or pentagon. The distance A B, or exterior side of the polygon, should not exceed the range of musketry, or about 200 yards. They are employed only in fortifying important positions, and require, accordingly, to be constructed in a more solid manner than other works of a temporary nature.

1825.



The last class of field-works comprehends *lines* of various descriptions. *Continued lines* are constructed to inclose a front, or connect principal works with one another by a continued parapet. They are constructed, according to circumstances, with redans, tenailles, or bastions, placed at certain intervals, seldom exceeding 180 yards. From the descriptions given above, the different forms of the *redan line*, *tenaille line*, and *bastion line*, will be readily conceived. Sometimes they are formed of a succession of faces and flanks at right angles. In this case they are called *lines-encremaillères.* The flanks are about a fourth of the length of the faces, and afford a defence to the ditches. Lines with intervals consist of isolated works, as redans or redoubts, placed at distances which should not exceed 200 yards, and so as to afford one another a mutual defence.

1826.



Besides the works now enumerated, various expedients are resorted to in order to prevent, or at least to render more difficult, the approaches of an enemy. Among these are *palisades*, *abatis*, *trous-de-coup*, *chevaux-de-frize*, *crows' feet*, &c.

The principal authors on fortification are Errard, Stevinus, Antoine de Ville, Compte de Pagan, Coe-

horn. Vauban, Mallet, Belidor, Blondel, Montalembert, Bisset, Bousmard, Carnot, Mouzé, &c. For a practical treatise the reader may be referred to the article "Fortification" in the *Encyc. Metropolitana* Also the works of D. H. Mahan, Professor of Military and Civil Engineering in the United States' Military Academy; and of H. W. Halleck, of the U. S. Army.

FOUNDATIONS. In preparing the foundation for any building, there are two sources of failure which must be carefully guarded against: viz. inequality of settlement, and lateral escape of the supporting material; and, if these radical defects can be guarded against, there is scarcely any situation in which a good foundation may not be obtained. It is therefore important that previous to the commencement of the work, soundings should be taken to ascertain the nature of the soil and the ray of the strata, to determine the kind of foundation; and the more important and weighty the superstructure, the more careful and deeper the examination.

Natural foundations.—The best foundation is a *natural* one, such as a stratum of rock, or compact gravel. If circumstances prevent the work being commenced from the same level throughout, the ground must be carefully *benched out*, i. e. cut into horizontal steps, so that the courses may all be perfectly level. It must also be borne in mind that all work will settle, more or less, according to the perfection of the joints, and therefore in these cases it is best to bring up the foundations to a uniform level, with large blocks of stone, or with concrete, before commencing the superstructure, which would otherwise settle most over the deepest parts, on account of the greater number of mortar joints, and thus cause unsightly fractures.

Many soils form excellent foundations when kept from the weather, which are worthless when this cannot be effected. In dealing with soils of this kind nothing is required but to keep them from the action of the atmosphere. This is best done by covering them with a layer of concrete, (see mortar.) For want of this precaution many buildings have been fractured from top to bottom by the expansion and contraction of their clay foundations during the alternations of drought and moisture, of frost and heat, to which they have been exposed in successive seasons.

Artificial foundations.—Where the ground in its natural state is too soft to bear the weight of the proposed structure, recourse must be had to artificial means of support, and, in doing this, whatever mode of construction be adopted, the principle must always be that of extending the bearing surface as much as possible; just in the same way, that, by placing a plank over a dangerous piece of ice, a couple of men can pass over a spot which would not bear the weight of a child. There are many ways of doing this—as by a thick layer of concrete, or by layers of planking, or by a net-work of timber, or these different methods may be combined. The weight may also be distributed over the entire area of the foundation by inverted arches.

The use of timber is objectionable where it cannot be kept constantly wet, as alternations of dryness and moisture soon cause it to rot, and for this reason concrete is very extensively used in situations where timber would be liable to decay.

In the case of a foundation partly natural and partly artificial, the utmost care and circumspection are required to avoid fractures in the superstructure; and it cannot be too strongly impressed that it is not an *unyielding*, but a *uniform yielding* foundation that is required, and that it is not the *amount*, so much as the *inequality*, of settlement that does the mischief.

The second great principle laid down at the commencement of this article was—To prevent the lateral escape of the supporting material. This is especially necessary when building in running sand, or soft clay, which would ooze out from below the work, and allow the superstructure to sink. In soils of this kind, in addition to protecting the surface with planking, concrete, or timber, it is often necessary to inclose the whole area of the foundation with piles driven close together; this is called *sheet-piling.*

Where there is a hard stratum below the soft ground, but at too great a depth to allow of the solid work being brought up from it without greater expense than the circumstances of the case will allow, it is usual to drive down wooden piles, often shod with iron, until their bottoms are firmly fixed in the hard ground. The upper ends of the piles are then cut off level, and covered with a platform of timber on which the work is built in the usual way. The piles are generally of about 1 foot diameter, and are driven at distances of from 2 to 3 feet from centre to centre.

Where a firm foundation is required to be formed in a situation where no firm bottom can be found within an available depth, piles are driven, to consolidate the mass, a few feet apart over the whole area of the foundation, which is surrounded by a row of sheet-piling to prevent the escape of the soil; the space between the pile heads is then filled to the depth of several feet with stones or concrete, and the whole is covered with a timber platform, on which to commence the solid work.

Foundations in water.—Hitherto we have been describing ordinary foundations; we now come to those cases in which water interferes with the operations of the builder, oftentimes causing no little trouble, anxiety, and expense.

Foundations in water may be divided under three heads: 1st, Foundations formed wholly with piles. 2d, Solid foundations laid *on* the surface of the ground, either in its natural state, or roughly levelled by dredging. 3dly, Solid foundations laid *below* the surface, the ground being laid dry by cofferdams.

Foundations formed wholly of piles.—The simplest foundations of this kind are those formed by rows of wooden piles braced together so as to form a skeleton pier for the support of horizontal beams; and this plan is often adopted in building jetties, piers of wooden bridges, and similar erections where the expense precludes the adoption of a more permanent mode of construction; an example of this kind is shown in Fig. 1827.

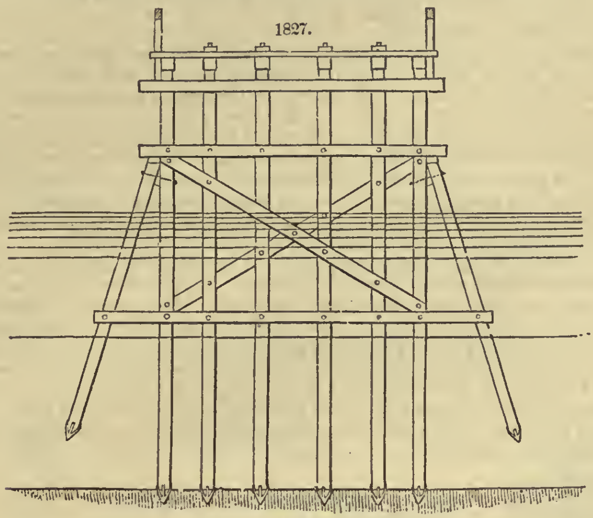
There is, however, an objection to the use of piles partly above and partly under water, that, from the alternations of dryness and moisture, they decay at the water-line; and in tidal waters, they are often rapidly destroyed by the worm.

To obviate the inconveniences attending the use of timber, cast-iron is sometimes used as a material for piles; but this again is objectionable in salt water, as the action of the sea-water upon the iron converts it into a soft substance which can be cut with a knife, resembling the lead used for pencils.

In situations where a firm hold cannot be obtained for a pile of the ordinary shape, such as shifting sand, Mitchell's patent screw piles may be used with great advantage. These piles terminate at the bottom in a large iron screw 4 feet in diameter, which, being screwed into the ground, gives a firm foothold to the pile. This is a very simple and efficient mode of obtaining a foundation where all other means would fail, and has been used in erecting light-houses on sand-banks with great success.

An ingenious system of cast-iron piling was adopted by Mr. Clark in the erection of the Town Pier at Gravesend, in forming a foundation for the cast-iron columns, supporting the superstructure of the T head of the pier. Under the site of each column were driven three cast-iron piles, on which an adjusting plate was firmly keyed, forming a broad base for the support of the column, which was adjusted to its correct position, and bolted down to the adjustiug plate.

1827.



SCALE.—20 feet=1 inch.

A kind of foundation on the same principle as piling has been lately much used in situations where ordinary piling cannot be resorted to with advantage. The method referred to consists in sinking hollow cast-iron cylinders until a hard bottom is reached. The interior of the cylinder is then pumped dry, and filled up with concrete or some equally solid material, thus making it a solid pier on which to erect the superstructure. The cylinders are made in lengths, which are successively bolted together as each previous length is lowered, the excavation going on at the bottom, which is kept dry by pumping. It often happens, however, in sinking through sand, that the pressure of the water is so great as to blow up the sand at the bottom of the cylinder; and, when this is the case, the operation is carried on by means of a large auger, called a miser, which excavates and brings up the materials without the necessity of pumping out the water. The lower edge of the bottom length of each cylinder is made with a sharp edge, to enable it to penetrate the soil with greater ease, and to enter the hard bottom stratum on which the work is to rest. This method was adopted by Mr. Redman in the erection of the Terrace pier at Gravesend.

Before closing our remarks on pile foundations, we must mention a very curious system of carrying up a foundation through loose wet sand, which is practised in India and China, and is strictly analogous to the sinking of cast-iron cylinders just described.

It consists in sinking a series of wells close together, which are afterwards arched over separately, and covered with a system of vaulting, on which the superstructure is raised. The method of sinking these wells is to dig down, as far as practicable, without a lining of masonry, or until water is reached; a wooden curb is then placed at the bottom of the excavation, and a brick cylinder raised upon it to the height of 3 or 4 feet above the ground. As soon as the work is sufficiently set, the curb and the superincumbent brick-work are lowered by excavating the ground under the sides of the curb, the peculiarity of the process being that the well-sinker works under water, frequently remaining submerged more than a minute at a time. These cylinders have been occasionally sunk to a depth of 40 feet.

Solid foundations simply laid on the surface of the ground.—Where the site of the intended structure is perfectly firm, and there is no danger of the work being undermined by any scour, it will be sufficient to place the materials on the natural bottom, the inequalities of surface being first removed by dredging or blasting.

Pierre perdue.—The simplest mode of proceeding is to throw down masses of stone at random over the site of the work until the mass reaches the surface of the water, above which the work can be carried on in the usual manner. This is called a foundation of "*pierre perdue*," or random work, and is used for breakwaters, foundations of sea-walls, and similar works. Plymouth breakwater is an example on a large scale.

Coursed masonry.—Another way, much used in harbor work, is to build up the work from the bottom (which must be first roughly levelled) with large stones, carefully lowered into their places; and this is a very successful method where the stones are of sufficient size and weight to enable the work

to withstand the run of the sea. The diving-bell affords a ready means of verifying the position of each stone as it is lowered.

Béton.—On the continent, foundations under water are frequently executed with blocks of béton or hydraulic concrete, which has the property of setting under water. The site of the work is first inclosed with a row of sheet piling, which protects the béton from disturbance until it has set. This system is of very ancient date, being described by Vitruvius, and was practised by the Romans, who have left us many examples of it on the coast of Italy. The French engineers have used béton in the works at Algiers, in large blocks of 324 cubic feet, which were floated out and allowed to drop into their places from slings. This method, which proved perfectly successful, was adopted in consequence of the smaller blocks first used being displaced and destroyed by the force of the sea.

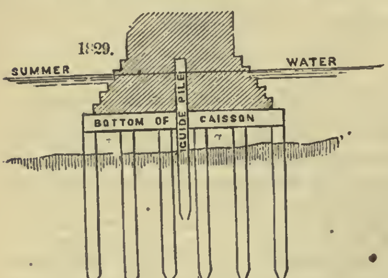
Caissons.—A caisson is a chest of timber, which is floated over the site of the work, and, being kept in its place by guide piles, is loaded with stone until it rests firmly on the ground. In some cases the stone is merely thrown in, the regular masonry commencing with the top of the caisson; which is sunk a little below the level of low water, so that the whole wood-work may be always covered, and the caisson remains as part of the structure. In others, the masonry is built on the bottom of the caisson, and when the work reaches the level of the water the sides of the caisson are removed.

Westminster Bridge, London, is a noted instance of the failure of this method of building. The bottom of the river has been scoured out to a depth of several feet since the erection of the bridge; and the foundations of the piers remained in a dangerous state until they were secured by driving sheet piling all around them, and underpinning the portions which had been undermined.

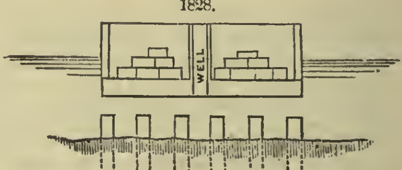
An improvement on the above method consists in dredging out the ground to a considerable depth, and putting in a thick layer of béton on which to rest the bottom of the caisson.

There is a third method of applying caissons which is practised in Europe, and which is free from the objections which commonly attend the use of caissons. A firm foundation is first formed by driving piles a few feet apart over the whole site of the foundation. The tops of the piles are then sawn off under water just enough above the ground to allow of their being all cut to the same level. The caisson is then floated over the piles, and, when in its proper position, is sunk upon them, being kept in its place by a few piles left standing above the others, the water being kept out of the caisson by a kind of well constructed round each of these internal guide piles, which are built up into the masonry. This method of building in caissons on pile foundations is shown in Figs. 1828 and 1829. The piers of the Pont du Val Benoît at Liége, which carries the railway across the Meuse, have been built on pile foundations in the manner here described.

1829.

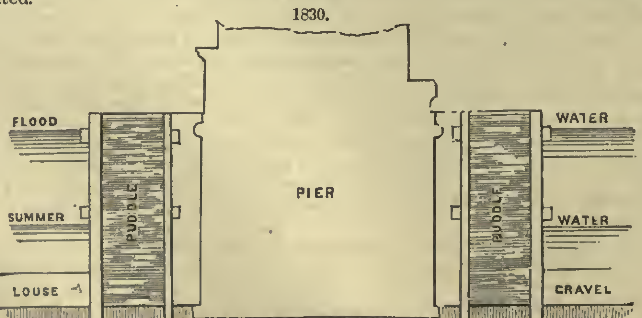


1828.



A similar plan of foundation was adopted in the construction of three of the piers of the railroad bridge across the Connecticut, at Springfied, Mass.; but to give the greatest stability to the work, the bottom was previously dredged, the piles were then driven, and cut off level considerably below the bed of the river. The spaces between the piles, and a few feet outside of them, was filled with béton, and raked off even with the top of the piles; the caisson was then floated into its position. The foundations of the other piers and abutments were of piles, but cofferdams were used, and the bottom laid dry and excavated.

1830.

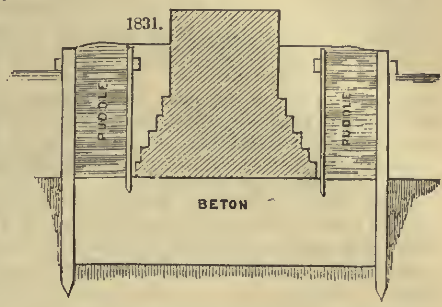


SCALE.—20 feet=1 inch.

Solid foundations laid in cofferdams.—There are many circumstances under which it becomes necessary to lay the bottom dry before commencing operations. This is done by inclosing the site of the

foundation with a water-tight wall of timber, from within which the water can be pumped out by steam power or otherwise. Sometimes, in shallow water, an earth embankment or a single row of sheet piles only is sufficient; but in deep water two or even four rows of piles will be required, the space between them being filled in with *puddle*, so as to form a solid water-tight mass, Fig. 1830. The great difficulties in the construction of a cofferdam are—1st, to keep it water-tight; and, 2d, to support the sides against the pressure of the water outside, which in tidal waters is sometimes so great as to render it necessary to allow a dam to fill to prevent its being crushed. Of the difficulties experienced in the construction of a cofferdam in deep water, and of the excavation for foundations, an interesting and instructive example may be found in the able report of Captain Turnbull, on the construction of the Potomac Aqueduct, published in the Civil Engineers' and Architects' Journal.

1831.



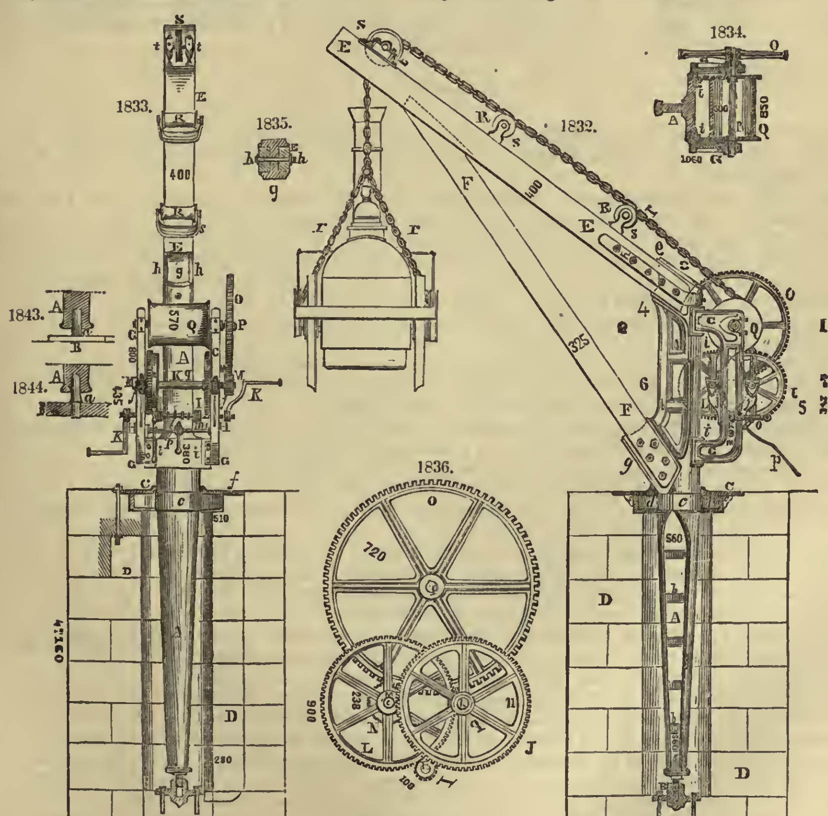
In order to save timber, and to avoid the difficulty of keeping out the bottom springs, it has been proposed by a French engineer, after driving the outer row, to dredge out the area thus inclosed, and fill it up to a certain height with béton. The cofferdam is then to be completed by driving an inner row of piles resting on the béton, and puddling between the two rows in the usual manner; and the masonry is carried up on the béton foundation thus prepared. This construction is shown in Fig. 1831. See Dry Dock.

FOUNDRY See Casting.

FOUNDRY CRANE. Fig. 1832.—Side elevation of the crane, and section of the masonry which supports it.

Fig. 1833.—Elevation of the geer side taken at right angles to Fig. 1832.

Fig. 1834.—Horizontal section on the line 1–2, Fig. 1832. Fig. 1835.—Section on the line 3–4.



Scale.—17 feet=4 inches.

Fig. 1836.—Elevation of geers and pinions.

Fig. 1837.—Shows the arrangement of the break; Fig. 1838.—A section of the same.

Figs. 1839 and 1840.—Horizontal section on the line 5–6; Fig. 1839 being the section of the frame which supports the geering; Fig. 1840, the section of the body or shaft of the crane.

Fig. 1841.—Plan of the cast-iron plate and friction wheels against which the shaft of the crane bears, and which facilitate its rotation. Fig. 1842.—Section of this plate on the broken line 7–8–9.

Figs. 1843 and 1844.—Show a different arrangement of steps from that already given, Figs. 1832 and 1833.

Explanatory Letters.

A, vertical shaft or body of the crane cast in one piece; *a*, a steel point (easily replaced when worn) at the lower end of the shaft, Fig. 1843. This step is cast with the base, and in Fig. 1844 it is steel, and fitted in the base plate.

B, cast-iron base or step-plate; *a*, steel step; *b*, ribs to strengthen the shaft; *e*, cylindrical-turned collar, against which the six strong cast-iron friction wheels *d* bear, maintaining the shaft perpendicular, and allowing it to turn freely.

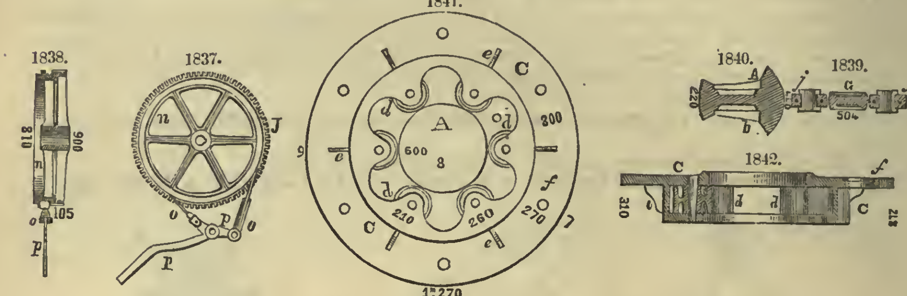
C, large plate cast in one piece, containing the wheels *d*; *e*, small corner pieces to strengthen the casting; *f*, man-hole to get at the step.

D, the masonry, in which is formed a circular well for the admission of the shaft A.

E, the oaken arm of the crane, supported by a strong brace F; *g g′*, shoes or sockets cast with the shaft, which receive the feet of the arm and brace. Fig. 1835 shows the same in section. *h*, an iron strap inclosing the top of the shaft and bolted securely to the arm E.

1841.

1838. 1837. 1840. 1839. 1842.



G, two cast-iron frames for the support of the geering, attached by bolts to the body of the crane through the ears *i*; *j j*, projections which support the boxes of the intermediate geer shaft; *k*, the cranks of wrought-iron.

H, shaft which can be moved endwise, on which are the two pinions I I′; *l*, a clutch which holds the shaft H in either of three positions; *m*, a rod connecting the two frames or sides G.

Operation.—When small weights are to be raised, the pinion I′ is thrown into geer with L; on the extremity of its shaft M the pinion N works in the geer O, on the same shaft P with the barrel Q, on which is wound the chain *r*, which, passing over the rollers R and the pulley S, is attached at its other extremity to the weight to be raised. Figs. 1832 and 1836.

But if the weight is considerable, the pinion I is thrown into gear with J, on whose shaft K is a pinion *q*, geering into L.

The break consists of two curved strips of wrought-iron *o o*, connected by a hinge encircling the pulley *n*, (on the shaft K,) and brought into more or less contact with it by the lever *p*, to the arms of which the other extremities of the metallic strips *o o* are attached.

FREEZING APPARATUS. An experiment of freezing water in vacuo, by its own evaporation, Fig. 1845, is shown by a shallow glass vessel, as a watch-glass, for containing the water to be frozen, which is supported over a wide glass basin, containing strong sulphuric acid, the whole covered by a low receiver. When the air is exhausted from the receiver, the acid will absorb the vapor from the water as rapidly as it is found, thereby abstracting the sensible heat from the water, till congelation ensues.

1845.

This is a mere matter of experiment, but within the last year an invention has been patented by which ice can be manufactured mechanically in large quantities, and it is supposed economically in low northern and southern latitudes. But it has not yet been sufficiently tested. It consists essentially of a force-pump, in which air is divested of its latent heat by mechanical compression, and an engine in which the same air is made to act expansively, and in the process to absorb from the water to be frozen the heat due to its increase of volume. But there are several auxiliary agents for giving this simple contrivance its greatest effective utility. Thus by an obvious arrangement of attaching the pump and engine to the opposite ends of a common beam, the power consumed in condensing air in the pump is, to a considerable degree, recovered in its expansion in the engine. At the same time the heat evolved by the compression of the air is extinguished by a jet of water thrown into the body of the force-pump by means of a smaller pump; while the heat necessary to impart to the expanding air the elasticity and mechanical force due to its volume is furnished through a similar pump, which takes from the cistern a portion of the liquid, and after injecting it into the expanding air in the engine, returns it to the same cistern. The cistern thus operates as a reservoir of cold, and as the sufficient means of abstracting heat from water which is to be converted into ice. It is proposed to use the same air over and over again; and thus the inventor attains the object of employing air which previous condensation has deprived of heat, and subsequent expansion has left at a lower temperature than the atmosphere.

FRICTION.—Friction is the resistance occasioned to the motion of a body, when pressed upon the surface of another body, which does not partake of its motion. Under these circumstances, the surfaces in contact have a certain tendency to adhere. Not being perfectly smooth, the imperceptible asperities which may be supposed to exist on all surfaces, however highly polished, become to some extent interlocked, and in consequence a certain amount of force is requisite to overcome the mutual resistance to motion of the two surfaces, and to maintain the sliding motion, even when it has been produced. By increasing the pressure, the resistance to motion is increased also; and on the other hand, by rendering the surfaces more smooth, and by lubrication, its amount is greatly diminished, but can never be entirely nulled.

Friction ought not strictly to be called a *force*, unless that term be in this case taken in a negative sense. The tendency of force, in the rigid meaning of the word, is to produce motion, whereas the tendency of friction is to destroy motion. An active force may indeed oppose motion in one direction, but only in virtue of a tendency to produce motion in the opposite direction; the peculiar characteristic of friction, on the other hand, is that it tends to destroy motion in every direction. It is essentially a passive resistance, a negative force, produced by pressure, to which it bears such relation that its amount may be measured by the same unit and enunciated in the same terms.

Nor is the measure of the friction between two surfaces in contact, properly the amount of force necessary to produce motion; but the amount of pressure necessary to balance the friction, and bring the body to a state of indifference to rest or motion. To understand this, let us suppose that a heavy hemispherical body rests with its flat surface upon a horizontal plane, and that the plane and the body are *perfectly smooth:* on this supposition there would be no friction, and the smallest possible force would put the body in motion. This condition being remarked, let us suppose that the surfaces in contact are of the ordinary kind, and that a weight of 10 lbs. attached to the movable body and made to act in the direction of the plane, is found to induce the same state of indifference to rest and motion as in the assumed case of no friction; we then conclude that 10 lbs. is the measure of the friction. As it is not always easy to determine when this condition is induced, it is better to regard the weight as an active force, which may, by addition, be made more and more intense, till motion of the body is actually induced. For the sake of convenience we may also speak of friction as a force and oppose it to other force: this can induce no erroneous conclusion.

Friction being then considered a *passive* force, its effect is the result of having other force to resist. If the measure of the friction of a body upon a plane be 10 lbs., and if an increasing force of 1, 2, 3 lbs., and so on, be applied, the friction increases with the force till the limit is reached; motion then ensues by the addition of any fraction of weight to the 10 lbs. The *force* of friction, although tending to prevent or destroy motion, may also be conceived to act like other force, in a direction opposite to that in which the balancing force acts; that is, in the language of mechanics, if the force P, applied to balance the friction F, act in the direction A B, the friction F acts in the direction B A. If then the body placed upon the horizontal plane, as supposed, be capable of motion in the two directions A B and B A, the body will remain at rest when acted upon by any force up to 10 lbs. in either of the directions. If therefore we distinguish the forces acting in opposite directions by the positive and negative symbols + and —, then the limits of equilibrium will be expressed by $P = \pm 10$ lbs., according to the usual mode of representing an equilibrium of forces.

A———————B

What is here stated in reference to a heavy body placed upon a horizontal plane, is equally true of the rubbing parts of every machine; the pressure upon the journals, by instituting resistance to motion, that is, friction, the equilibrium will subsist between certain limits, and it is only by transgression of those limits on one side, that the equilibrium is destroyed and motion established. To determine accurately those limits in machines, is one of the most important problems in mechanics; and it has only been by the elaborate and admirably conducted experiments of the French Academy, that a sufficiently extensive code of data has been attained possessing the requisite evidence of accuracy, to warrant implicit confidence in the truth of the following important laws, which include the whole doctrine of friction as a retarding force in the dynamical operation of machines.

LAW I.—*The friction bears to the pressure upon the surfaces in contact, a ratio which is constant for the same materials with the same condition of surfaces.*

To express this somewhat more familiarly: If the surface of one body be pressed upon that of another, with a certain force, and if that force be doubled, the friction will be doubled; and if the force pressing them together be tripled, the friction will be tripled; and so on. Thus if a piece of cast-iron weighing 100 lbs. be laid with its plane surface upon a larger surface of brass, level, and it be found that a certain weight made to act in the direction of the supporting plane, is just sufficient to induce in the mass of iron a state of indifference to rest or motion, that weight is the measure of the friction between the two surfaces; and if these be well polished and clean, and without lubricant of any kind, the weight which it will be necessary to apply will be 14·7 lbs. If now we place a weight of 100 lbs. upon the mass of cast-iron, making the gross pressure upon the surfaces in contact 200 lbs., the weight necessary to balance the friction will be increased in the same ratio, that is $F = 14{\cdot}7 \text{ lbs.} \times 2 = 29{\cdot}4$ lbs. Another weight of 100 lbs., placed on the first, making the pressure 300 lbs., will increase the measure of friction to $14{\cdot}7 \text{ lbs.} \times 3 = 44{\cdot}1$ lbs. And so on for every increment of pressure as expressed by the law.

If now we divide the weight which balances the friction, by the weight which measures the pressure upon the surfaces, we obtain a ratio which is manifestly constant, since the pressures upon the surfaces and the weights balancing the friction, corresponding to those pressures, are respectively multiples throughout, of the first units 100 lbs. and 14·7 lbs. Thus we have

$$\frac{14{\cdot}7 \text{ lbs.}}{100 \text{ lbs.}} = \frac{29{\cdot}4 \text{ lbs.}}{200 \text{ lbs.}} = \frac{44{\cdot}1 \text{ lbs.}}{300 \text{ lbs.}} = {\cdot}147$$

From this then it appears, that knowing the measure of the friction for a given unit of pressure upon

the surfaces in contact, these remaining constant in kind and condition, the measure of the friction answering to any other pressure may be deduced. In the case assumed we have a common ratio of ·147 between the pressures of contact, and the measures of the friction; this ratio therefore being known, together with the pressure in the particular case, the measure of the friction for that case will also be known. Putting P = the pressure upon the rubbing surfaces; F = the measure of the friction; and $f = \frac{F}{P}$; then we have $F = f \times P$.

In this formula the ratio f of the friction to the pressure is termed the *coefficient of friction.* Its value, as already announced, is constant for the same materials and condition of the surfaces in contact; but varies as these vary. Thus in the particular case taken, the value is ·147; but if the rubbing surfaces be *unctuous,* it is reduced to ·132; that is, by repetition of the experiments described above, with this new condition of surfaces, we should find

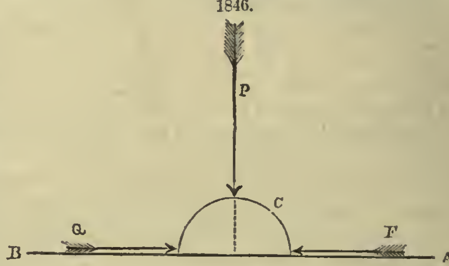
$$\left.\begin{array}{l} F = f \times P = \cdot 132 \times 100 \text{ lbs.} = 13{\cdot}2 \text{ lbs.} \\ F = \quad \cdot \quad = \cdot 132 \times 200 \text{ lbs.} = 26{\cdot}4 \text{ lbs.} \\ F = \quad \cdot \quad = \cdot 132 \times 300 \text{ lbs.} = 39{\cdot}6 \text{ lbs.} \end{array}\right\} \text{measures of the friction.}$$

If a cast-iron plate be substituted for the brass plate used as the supporting surface, and the surfaces be first well polished, clean, and dry, next wetted with water, and lastly, be freely lubricated with hogs' lard, we have the three values $f = \cdot 152$, $f = \cdot 314$, $f = \cdot 07$ answering to these conditions; hence taking P as before, we have by substitution in the formula $F = f \times P$, the following results:

	Surfaces wet.	Surfaces dry.	Surfaces lubricated.
For 100 lbs.	F = 15·2 lbs.	F = 31·4 lbs.	F = 7 lbs.
.... 200 lbs.	F = 30·4 lbs.	F = 62·8 lbs.	F = 14 lbs.
.... 300 lbs.	F = 45·6 lbs.	F = 93·2 lbs.	F = 21 lbs.

The determination of f, that is, of the coefficient of friction, for different kinds of materials, and also for different states of their surfaces in contact, is manifestly the business of experiment. There is no *a priori* rule by which it can be arrived at in the present state of our knowledge of the physical properties of bodies.

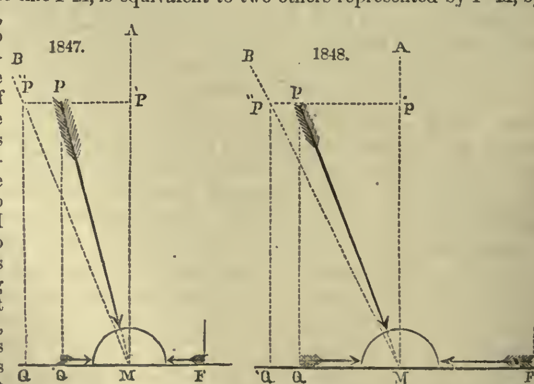
1846.



There is another mode of considering the subject here discussed, which has its expression likewise in the subjoined table, and which it becomes us therefore to explain.—Let us suppose the arrangement as in the experiments described, and that A B, Fig. 1846, is the supporting surface, and C the mass of cast-iron resting upon it. Again, let the pressure of the mass acting perpendicularly to the surfaces in contact, be denoted by P, and let the force Q, parallel to the surfaces, be applied to slide the body towards A. Then since the forces P and Q act in directions perpendicular to one another, they manifestly cannot counteract one another; consequently, were there no third force F opposed to Q, the system would be unbalanced, and there would obviously be motion of the mass C in the direction of the second force. The third force F is the friction, and so long as the force Q does not exceed its limit, the system must remain stable.

This being understood, let us suppose that the force P, Figs. 1847 and 1848, instead of having its direction perpendicular to the surfaces in contact, is impressed obliquely; if then the parallelogram of forces P′ Q be completed, the force P, represented by the line P M, is equivalent to two others represented by P′ M, by which the surfaces are pressed together, and Q M which tends to give motion to the body in a direction parallel to the surfaces. Now the actual friction F of the surfaces must be a certain fraction of P M; let it be M Q′ = M F and complete the parallelogram P′ Q′, and draw its diagonal P″ M. Since then M Q′ represents the friction of the body upon the plane, that is, the resistance called into action by the force P M, and since Q M represents the whole tendency of P M to produce motion of the body, it follows that the body will move or not according as Q M is greater or less than Q′ M, that is, as P P′ is greater or less than P″ P′, or as the angle P M A is greater or less than the angle B M A. These conditions are shown in the diagrams: in the first there would be motion induced by the preponderance of force Q Q′; in the second, the friction F = M Q′ being greater than Q M, the system would remain at rest.

1847. 1848.



The angle B M A is termed the *limiting angle of resistance*, or more shortly the *angle of friction.* Its tangent is the fraction $\frac{P' P''}{P' M} = \frac{M Q'}{P' M}$, which is the *coefficient of friction.* The angle is manifestly

the same for surfaces of the same nature, whatever be the actual amount of the impressed force P; but is different for different surfaces.

From this then it appears that the force impressed upon the surface of a solid body, at rest, by the intervention of another solid body, will be destroyed, whatever be its direction, provided only the angle, which the direction makes with the perpendicular to the surface, do not exceed the angle of friction of that surface; and that this is true, however *great* the force may be. Also that if the direction of the force lie without this angle, it cannot be sustained by the resistance of the surfaces in contact; and that this is true, however *small* the force may be.

This beautiful principle of the angle of friction was first examined by the celebrated mathematician Euler. His mode of demonstration was different, and in some respects, more obvious; it consisted in showing at what angle of inclination a body would begin to slide down an inclined plane. By similar reasoning to that employed above, it is readily determined that the body will just be sustained on the inclined plane, without slipping, when the inclination of the plane is equal to the limiting angle of resistance; and the tangent to the angle of inclination is the ratio of the friction to the pressure. Knowing therefore this angle the coefficient of friction is known, and conversely, the coefficient being known the inclination is likewise known.

Law II.—*The measure of friction is independent of the extent of surface, the pressure and the condition and character of the surfaces remaining the same.*

This important property of friction was also first announced by Amontons; and finally established by M. Morin, who found it to hold good, even at pressures so great that the surfaces were considerably abraded. It might, in fact, be inferred from the law previously explained, to which it is nothing more than a corollary; for by increasing the surface which supports the pressure, the amount of pressure upon every point of the surface is diminished; and although there are more rubbing points, their aggregate amount of friction must of necessity be the same as before. It can readily, however, be conceived that there will be a limitation to the proposition, when the rubbing surface is so small in proportion to the pressure, that abrasion of the surfaces ensues to an immoderate extent, (as in the operations of cutting and hewing, which are not contemplated in the enunciation;) but if the surface is sufficient to render the cutting and wearing, and also the heating, imperceptible, then the friction is as the pressure, and independent of the extent of the surfaces.

Law III.—*The friction is entirely independent of the velocity of continuous motion.*

This fact results from the experiments of M. Morin; but it must not be supposed that it implies that the same amount of mechanical power is expended in overcoming friction at all velocities of motion. On the contrary, the law implies that the amount of mechanical power expended in overcoming the friction, is proportionate to the velocity of the motion, since a constant force must be exerted with a varying velocity. For instance, whatever amount of mechanical power may be lost by the friction of the parts of any machine, while moving with a given velocity, (supposing the pressure on the rubbing parts to remain constant,) a double power will be lost by friction when the machine moves with a double velocity; and so on in proportion. It also follows that the amount of mechanical power lost by friction will, in all cases, be proportionate to the space passed over by the surfaces in contact without regard to time; for instance, the amount of mechanical power, which must be expended to move a carriage for a given distance along a level railway, will be the same whether it travels quickly or slowly over that distance. The friction is, in short, a *uniformly* retarding force, and is always the same fraction of the pressure, however great, (within certain limits,) and however small that pressure may be.

From the preceding discussion, it then appears that the whole doctrine of friction may be reduced to the single proposition that the friction is proportionate to the pressure upon the surfaces in contact, and independent of the extent of these surfaces, and of the velocity of their motion. There is still, however, to be noted the extreme case of *no velocity* after the two surfaces have remained for a considerable time in contact. If a body be laid upon an inclined plane, and the angle of this be very slowly increased, the body will not begin to slide down when the inclination is exactly equal to the angle of friction. This condition of *quiescent friction* was also investigated by M. Morin, and a summary of the results which he obtained will be found in the subjoined table. It must, however, be observed that this species of friction does not only differ in its *amount* from the friction of surfaces in continuous motion, but likewise in its nature, especially in this, that the friction of quiescence is subject to causes of variation and uncertainty from which the friction of motion is exempt. Nor does the variation appear to depend upon the extent of the surfaces of contact; for with different pressures, the ratio of the friction to the pressure, that is, the coefficient of friction, varied greatly, although the surfaces in contact remained the same. This uncertainty appears at first to complicate the whole question; but fortunately the difficulty is removed by a second very important fact developed accidentally in the course of the experiments; namely, that by the slightest *jar* or *shock*, even the most imperceptible *movement* of the surfaces of contact, the friction is made to pass from a state accompanying *quiescence* to that entirely different state of friction which accompanies *motion;* and as every machine, of whatever kind, may be considered subject to such shocks, it is evident that the state of friction to be made the basis on which all questions of statics are to be determined, should be that which accompanies continuous motion, the laws of which are uniform and precise.

The actual measure of the friction of two rubbing surfaces for a given pressure, must obviously depend upon the hardness and smoothness of the surfaces, as upon these depend the extent of the mutual penetration and interlocking of the insensible asperities. It was also supposed to be established by the experiments of Coulomb, that the friction between similar substances is greater than between substances which are dissimilar; but this conclusion, although it has been long received as a general law of friction, is not sanctioned by the investigations of M. Morin, which are in every respect more worthy of confidence than those upon which the assumption is based.

When lubrication is employed to lessen the friction, a distinction is to be made between the case in

which the surfaces are simply *unctuous* and in intimate contact, and the case in which the surfaces are wholly separated from one another by an interposed stratum of the unguent. If the pressure upon the surfaces of contact of given dimensions be increased beyond a certain limit, the latter of these cases passes into the first; the stratum of unguent being pressed out, and the unctuous surfaces which it separated from one another being brought into intimate contact. As long as either of these two states remains, the laws of its friction are not affected by the pressure of the unguent; but in the transition from the one state to the other, an exception is made to the independence of the friction upon the extent of the surfaces of contact; for supposing the extent of two surfaces of contact between which a stratum of unguent is interposed, and which sustains a given pressure, to be continually *diminished*, it is evident that the portions of this pressure which take effect upon each element of the surfaces of contact will be continually increased, and that they may thus be so increased, as to press out the interposed stratum of unguent, and cause the state of the surfaces to pass into that designated as *unctuous*, thereby changing the coefficient of friction. The second law of friction then, which is known as the law of "the independence of the surface," is to be received in the case where a stratum of unguent is interposed, within certain limits.

The observation made by M. Morin, that whenever two perfectly clean surfaces were made to move upon one another, both were worn into alternate ridges and channels, accompanied by the formation of a powder, is not without its practical value. During the experiments this effect was invariably produced whenever the pressures were very great, and was commonly attended in the experiments upon the friction of woods, with the odor of burning wood. The effect was also found to be very considerable in the case of fibrous metals, such as wrought-iron, sliding upon each other; less in the case of granular metals, such as cast-iron, sliding upon the fibrous; and least of all when the granular metals were slid upon one another.

This was found not to be the case when the surfaces of contact were unctuous, and the circumstance suggested to M. Morin what appears to be a true explanation of the remarkable difference between his results and those of Coulomb. He conceives that in the experiments of that celebrated engineer, the requisite precautions had not been taken to avoid unctuosity—such as might present itself accidentally in polishing the surfaces. In that case abrasion would be prevented, and instead of a new surface being continually presented by wear, the same surface would remain, and receive by the motion continually a more perfect polish.

Rolling friction.—The theory of rolling friction is by no means firmly grounded. We know that it increases with the pressure, and that it is greater for a smaller than for a larger diameter of the rolling body; but in what algebraical dependence this friction stands to the pressure and diameter of the rolling body, cannot as yet be considered as determined. Coulomb made only a few experiments with rollers, from two to twelve inches thick, of lignum-vitæ and elm, which were rolled along a surface of oak, by means of a thin thread passing over a roller whose extremities were stretched by unequal weights. From the results of these experiments, rolling friction appears to increase directly with the pressure and inversely with the diameter of the roller, so that the force necessary to overcome this friction may be expressed by $F = f\frac{R}{r}$, if R be the pressure, r the radius of the roller, and f the coefficient of friction derived from experiment. If r be given in inches, then from these experiments, for rolling upon compressed wood, $f = \cdot 0189$; if the wood be elm, $f = \cdot 031$. These formulas suppose that the force F acts at the circumference of the roller, but if the force be applied to the axis of the rolling bodies, by which, as in every description of carriage, axle friction ensues, the required force is 2 F, because here the arm is only half that of the diameter with respect to the point of application.

Explanation of the tables.—The first and most extensive of the following tables, contains a very complete summary of M. Morin's experiments of the friction of plane surfaces sliding upon another. It embraces the three conditions of clean and unctuous surfaces, and surfaces between which a stratum of the lubricant is interposed. The coefficient of friction is given for each of those conditions for both the friction of motion and the friction of quiescence, and also the limiting angle of resistance answering to the coefficients of friction in the cases of clean and unctuous surfaces. The sliding surfaces were varied from ·03336 to 2·7987 square feet, and the pressures from 88 lbs. to 2205 lbs. The surfaces of the woods were planed, and those of metal filed and polished with the utmost care; and when the friction of the clean surfaces was to be determined, any unctuosity was especially guarded against. In the experiments upon unctuous surfaces, the unguent was carefully wiped off, so that no interposing layer of it should prevent their intimate contact. In the experiments to determine the friction with unguents interposed, the extent of the surfaces bore such a relation to the pressure, that a stratum of the lubricant was retained between them. The relations kept in view were such as are commonly found in the larger class of machines in which the adhesion of the lubricant to the surfaces of contact may, as respects opposition to motion caused by its viscidity, be overlooked as altogether insignificant compared with the friction. As respects the nature of the substance used in lubrication, it will be observed by comparison of the coefficient of the friction of motion, that with hog's lard and olive oil, surfaces of wood on metal, wood on wood, metal on wood, and metal on metal, have all very nearly the same friction, the value of the coefficient being in all those cases included between 0·07 and 0·08. With tallow the coefficient is the same except in the case of metals upon metals; this lubricant seems therefore less suited for metallic surfaces than the others named.

The second table contains the results of experiments upon the friction of axles of different materials upon their bearings. It requires no further explanation, but attention may be directed to the advantage to be derived from attention to the mode in which the lubricating substance is applied.

SUMMARY OF M. MORIN'S EXPERIMENTS OF THE FRICTION OF PLANE SURFACES.

SLIDING SURFACE.	SURFACE AT REST.	STATE OF THE SURFACES.		Friction of motion. Co-efficient of friction.	Friction of motion. Limiting angle of resistance.	Friction of quiescence. Co-efficient of friction.	Friction of quiescence. Limiting angle of resistance.
Oak	Oak	Direction of fibres parallel to the motion...............	Without lubrication.......	0·478	25° 33′	0·625	32° 1′
			Lubricated with tallow ..	0·975	....	0·160	....
			Lubricated with lard	0·067	....	....	....
do.........	do.........	Fibres of the moving surface perpendicular to the motion.	Without lubrication.......	0·324	17 58	0·540	28 23
			Unctuous................	0·143	8 9	0·314	17 26
			Lubricated with tallow ..	0·083	....	0·254	....
			Lubricated with lard	0·072	....	....	....
			Lubricated with water...	0·250	....	....	....
do...	do.........	Fibres of both surfaces perpendicular to the direction of the motion	Without lubrication	0·336	18 35	....	....
do.........	do.........	Fibres of the moving surface perpendicular to the surface of contact, and those of the quiescent surface parallel to the motion	Without lubrication	0·192	10 52	0·271	15 10
do.........	do.........	Fibres of both surfaces perpendicular to the surface of contact, or the pieces end to end.	Without lubrication.....	....	....	0·43	23 17
Oak	Elm	Fibres parallel to the motion.	Without lubrication.......	0·246	13 50	0·376	20 37
			Unctuous	0·136	7 45	....	....
			Lubricated with dry soap	0·136	....	....	....
			Lubricated with tallow ..	0·073	....	0·178	....
			Lubricated with lard	0·066	....	....	....
Elm	Oak	Fibres parallel to the motion..	Without lubrication.......	0·432	23 22	0·694	34 46
			Unctuous................	0·119	6 48	0·420	22 47
			Lubricated with dry soap	0·137	....	0·411	....
			Lubricated with tallow ..	0·070	....	0·142	....
			Lubricated with lard	0·060	....	....	....
		Fibres of the moving surface perpendicular to the motion..	Without lubrication......	0·450	24 16	0·570	29 41
Beech	Oak	Fibres of both surfaces parallel to the motion..............	Without lubrication.......	0·360	19 48	0·530	27 56
			Unctuous................	0·330	18 16	....	....
			Lubricated with tallow....	0·550	....	....	....
Ash and Sorrel wood ...	Oak	Fibres of both surfaces parallel to the motion..............	Without lubrication.......	0·400	21 49	0·570	29 41
Fir	Oak		....do.........do..........	0·355	19 33	0·520	27 29
Pear-tree	Oak		....do.........do..........	0·370	20 19	0·440	23 45
Wrought-iron	Oak		....do.........do..........	0·619	31 47	0·619	31 47
Cast-iron	Oak		Lubricated with dry soap	0·214	....	....	....
			Lubricated with tallow ..	0·085	....	0·108	....
			Tallow	0·098	....	....	....
Oak	Wrought-iron	.....do......... .do.....	Greased and saturated with water................	0·256	....	0·649	....
Elm	Elm		Without lubrication.......	0·252	14 9	....	....
Wrought-iron	do..........		Unctuous................	0·138	7 52	....	....
			Lubricated with tallow ..	0·078	....	....	....
			Lubricated with lard	0·076	....	....	....
			Lubricated with olive oil.	0·055	....	....	....
Cast-iron	Oak	.......do............do.....	Without lubrication.......	0·490	26 7	....	....
			Unctuous................	0·107	6 7	0·100	5 43
			Lubricated with dry soap	0·189	....	....	....
			Lubricated with tallow ..	0·078	....	0·100	....
			Lubricated with lard or olive oil	0·075	....	0·100	....
			Greased and saturated with water..................	0·218	....	0·646	....
Oak	Cast-iron ...	Fibres of the wood parallel to the motion.	Lubricated with tallow...	0·80	....	....	....
		do.........do. perpedicular to the motion.	Without lubrication......	0·372	20 25	....	....
Cast-iron	Elm	do.........do. parallel to the motion.	....do.........do..........	0·195	11 3	....	....
			Surface unctuous with tallow	0·125	7 8	....	....
			Surface unctuous with lard	0·137	7 49	....	....
			Lubricated with tallow ..	0·077	....	....	....
			Lubricated with lard	0·091	....	....	....
			Lubricated with olive oil.	0·061	....	....	....
Elm	Cast-iron	.....do.............do.....	Surfaces unctuous.........	0·135	7 42	0·098	5 36
			do. lubricated with tallow	0·066	....	....	....
Hornbeam ...	do.		Without lubrication.......	0·394	21 31	....	....
Pear-tree	do.		....do.........do..........	0·436	23 34	....	....
Copper	Oak		....do.........do..........	0·617	31 41	0·617	31 41
			Surfaces unctuous.........	0·100	5 43	....	....
			Lubricated with tallow....	0·069	....	0·100	....
Wrought-iron	Wrought-iron	Fibres of both surfaces parallel to the motion.......	Without lubrication.......	0·138	7 52	0·137	7 49
			Surfaces unctuous.........	0·177	10 3	....	....
			Lubricated with tallow ..	0·082	....	....	....
			Lubricated with lard	0·081	....	....	....
			Lubricated with olive oil.	0·070	....	0·115	....
Wrought-iron	Cast-iron	.......do....... ....do.....	Without lubrication.......	0·194	10 59	0·194	10 59
			Surfaces unctuous........	....	....	0·118	6 44
			Lubricated with tallow ..	0·103	....	....	....
			Lubricated with lard	0·076	....	....	....
			Lubricated with olive oil.	0·066	....	0·100	5 43

SUMMARY OF M. MORIN'S EXPERIMENTS OF THE FRICTION OF PLANE SURFACES.—(Continued.)

SLIDING SURFACE.	SURFACE AT REST.	STATE OF THE SURFACES.		Friction of motion. Co-efficient of friction.	Friction of motion. Limiting angle of resistance.	Friction of quiescence. Co-efficient of friction.	Friction of quiescence. Limiting angle of resistance.
Cast-iron	Wrought-iron	Fibres of both surfaces parallel to the motion	Surfaces unctuous	0·143	8° 9′	....	....
			Lubricated with tallow	....	....	0·100	5°43′
			Without lubrication	0·152	8 39	0·162	9 13
			Surfaces unctuous	0·144	8 12	....	....
Cast-iron	Cast-iron	do. do.	Lubricated with water	0·314	....	....	....
			Lubricated with soap	0·197	....	....	....
			Lubricated with tallow	0·100	5 43	0·100	5 43
			Lubricated with lard	0·070	....	0·100	....
			Lubricated with olive oil	0·064	....	....	....
			Lubricated with lard and pl'bago	0·055	....	....	....
Wrought-iron	Bronze	Fibres parallel to motion	Without lubrication	0·172	9 46	....	....
			Surfaces unctuous	0·160	9 6	....	....
			Lubricated with tallow	0·103	....	....	....
			Lubricated with lard	0·075	....	....	....
			Lubricated with olive oil	0·078	....	....	....
Bronze	Wrought-iron	do. do.	Without lubrication	0·161	9 9	....	....
			Surfaces unctuous	0·166	9 26	....	....
			Lubricated with tallow	0·081	....	....	....
			Lubricated with lard and pl'bago	0·089	....	....	....
			Lubricated with olive oil	0·072	....	....	....
Cast-iron	Bronze	do. do.	Without lubrication	0·147	8 22	....	....
			Surfaces unctuous	0·132	7 22	....	....
			Lubricated with tallow	0·103	....	....	....
			Lubricated with lard	0·075	....	....	....
			Lubricated with olive oil	0·078	....	....	....
Bronze	Cast-iron	do. do.	Without lubrication	0·217	12 15	....	....
			Surfaces unctuous	0·107	6 7	....	....
			Lubricated with tallow	0·086	....	0·106	....
			Lubricated with olive oil	0·077	....	....	....
Bronze	Bronze	do. do.	Without lubrication	0·201	11 22	....	....
			Surfaces unctuous	0·134	7 38	0·164	9 19
			Lubricated with olive oil	0·058	....	....	....
Brass	Cast-iron	do. do.	Without lubrication	0·189	10 49	....	....
			Surfaces unctuous	0·115	6 34	....	....
			Lubricated with tallow	0·072	....	0·103	....
			Lubricated with lard	0·068	....	....	....
			Lubricated with olive oil	0·066	....	....	....
Steel	Cast-iron	do. do.	Without lubrication	0·202	11 26	....	....
			Lubricated with tallow	0·105	....	0·108	....
			Lubricated with lard	0·081	....	....	....
			Lubricated with olive oil	0·079	....	....	....
Steel	Wrought-iron	Fibres of iron parallel to the motion	Lubricated with tallow	0·093	....	....	....
			Lubricated with lard	0·076	....	....	....
Steel	Bronze		Without lubrication	0·152	8 39	....	....
			Lubricated with tallow	0·056	....	....	....
			Lubricated with olive oil	0·053	....	....	....
			Lubricated with lard and pl'bago	0·067	....	....	....
Black leather (as used for light straps)	Oak	Fibres of the oak parallel; leather laid flat	Without lubrication	0·265	14 51	0·74	36 31
		do. polished and hardened by hammering	do. do.	0·296	16 30	....	....
Ox hide (such as used for strong belts &c.)	do.	Fibres of wood parallel, rough	Without lubrication	0·52	27 29	0·605	31 11
		Fibres of wood parallel, smooth	Without lubrication	0·335	18 31	0·43	23 17
			Leather saturated with water	0·29	....	0·79	....
do.	Cast-iron	do. do.	Surface unctuous	0·229	12 54	0·267	14 57
			Greased and saturated with water	0·365	....	....	....
			Lubricated with tallow	0·159	....	....	....
			Lubricated with olive oil	0·133	....	0·122	....
do.	Brass	do. do.	Surfaces unctuous	0·244	13 43	....	....
			Lubricated with tallow	0·241	....	....	....
			Lubricated with olive oil	0·191	....	....	....
Hemp	Oak	Fibres of hemp not twisted and placed in a direction perpendicular to those of the motion; fibres of the oak parallel to the motion	Greased and saturated with water	0·332	....	0·869	....
Hemp	Cast-Iron	Fibres of hemp, as above	....	....	....	....	....
Hemp-twist	Cast-iron	do. do.	Lubricated with tallow	0·194	....	....	....
			Lubricated with olive oil	0·153	....	....	....
Hemp-band	Oak	Fibres of the wood and direction of the cord parallel to the motion	Without lubrication	0·52	27 29	0·64	32 38
Hemp-plait band of small cords	do.	do. do.	do. do.	0·32	17 45	0·50	26 34
Old cordage 1¼ in. diam.	do.	do. do.	do. do.	0·52	27 29	0·79	38 19

RATIOS OF FRICTION TO PRESSURE FOR AXLES IN MOTION IN THEIR BEARINGS.

I.—ACCORDING TO MORIN'S EXPERIMENT.

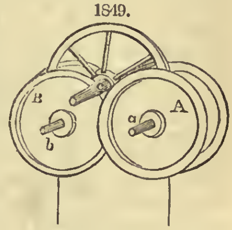
Designation of surfaces in contact.	State of Surfaces and nature of Lubrication.							
	Dry or slightly greasy.	Greasy, and wet with water.	Lubricated, and wet with water.	Oil, tallow, or hogs' lard. Supplied in the ordinary manner.	Oil, tallow, or hogs' lard. The grease continually renewed.	Purified very soft grease.	Hogs' lard with plumbago.	Greasy, very soft to the touch.
Bronze on bronze	....	....	....	0·079	....	....	....	....
do. on cast-iron	....	....	....	....	0·049	....	....	....
Iron on bronze	0·251	0·189	....	·075	0·054	0·090	0·111	....
do. on cast-iron	....	....	...	·075	0·054	....	....	....
Cast-iron on cast-iron	....	0·137	0·079	·075	0·054	....	....	....
do. on bronze	0·194	0·161	....	0·075	0·054	0·065	....	0·137
Iron on lignum-vitæ	0·188	....	....	0·125	....	....	....	0·166
Cast-iron on do.	0·185	....	....	0·100	0·92	....	0·109	0·140
Lignum-vitæ on cast-iron	....	....	....	0·116	....	....	....	0·153
do. on lignum-vitæ.	....	....	....	....	0·170	....	....	....

II.—ACCORDING TO COULOMB'S EXPERIMENT.

	Dry.	Olive-oil.	Hogs' lard.	Tallow.	Greasy.	Old lubrication.	Observations.
Iron on copper	0·155	0·130	0·120	0·085	0·127	0·133	The number relative to the friction of iron on wood is deduced from a pulley, the lubrication of which, or the nature of the axle and bearings, are not mentioned by Coulomb.
Iron on wood	....	....	....	0·050	....		
Green-oak on lignum-vitæ	....	....	....	0·038	0·060	0·070	
do. on elm	....	....	....	0·030	0·050	....	
Box on lignum-vitæ	....	....	....	0·043	0·070	....	
Box on elm	....	....	....	0·035	0·050	....	

FRICTION ROLLERS. The obstruction which a cylinder meets in rolling along a smooth plane is quite distinct in its character, and far inferior in its amount to that which is produced by the friction of the same cylinder drawn lengthwise along a plane. For example, in the case of wood *rolling* on wood, the resistance is to the pressure, if the cylinder be small, as 16 or 18 to 1000; and if the cylinder be large, this may be reduced to 6 to 1000. The friction from sliding, in the same cases, would be to the pressure as 2 to 10, or 3 to 10, according to the nature of the wood. Hence, by causing one body to roll on another, the resistance is diminished from 12 to 20 times. It is therefore a principle in the composition of machines that attrition should be avoided as much as possible, and rolling motions substituted whenever circumstances admit.

1849.

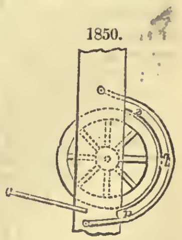


On this principle depends the advantages resulting from the application of *friction wheels* and *friction rollers.* The extremity of an axle C, instead of resting in a cylindrical socket, is made to rest on the circumferences of two wheels, A and B, to the axles of which, *a* and *b*, the friction is transferred, and consequently diminished in the ratio of the radius of the wheel A to the radius of the axle *a*. This ingenious contrivance appears to have first been applied by M. Sulley, in the year 1716.—*Descr. Abrigée d'une Horoge, &c.*, Bordeaux, 1716.

The following are deductions from Coulomb's experiments relative to the friction of rolling bodies: 1. Like the friction of sliding bodies, it is a constant force. 2. It is affected by the nature of the surface so far as polish is concerned; but is not lessened by the interposition of unctuous substances. 3. It is less between heterogeneous than between homogeneous substances. 4. It is directly proportional to the pressure. 5. It has no relation to the magnitude of the surface. 6. It is much less than in the case of sliding surfaces, and varies in the inverse ratio of the diameter of the rolling body.

The friction of the axle of a wheel or pulley (whether the axle itself turns, or the wheel turns on the axle) is of a different kind from that of a cylinder rolling on a plane. It is less than that of sliding but greater than that of rolling bodies, and follows in all respects the laws of the friction of sliding bodies. A great advantage is here obtained by greasing the surfaces. By the application of fresh tallow the friction is reduced to one half.

1850.



Friction is one of the most effectual means of arresting motion. In some machines, especially wind-mills, cranes, &c., it is very important to have the power of suddenly stopping the machine, or at least of controlling its motion. This is effected by means of a strong bridle of wood or iron, *a b c*, fixed at one end, and at the other furnished with a lever, by pressing on which, the bridle is brought into close contact with the broad rim of a wheel which participates in the general motion of the machine. The bridle may be made to bear on the whole circumference of the wheel; and a moderate pressure on the lever will produce a resistance sufficient to destroy the motion almost instantaneously.

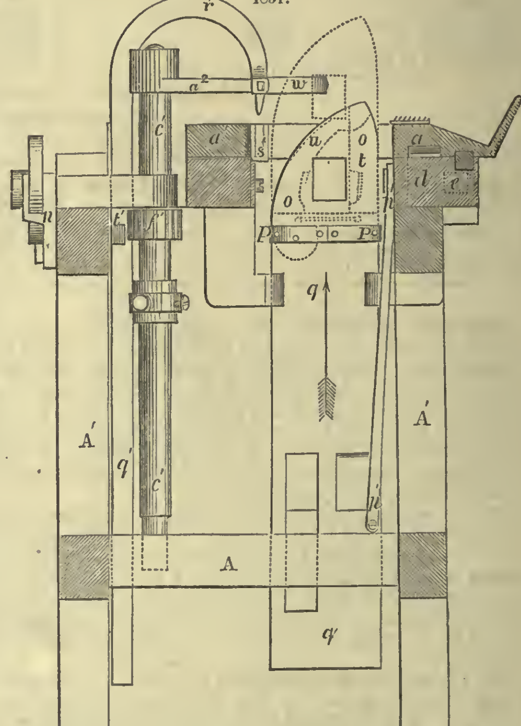
Coulomb's experiments were also directed to ascertain the resistance arising from the rigidity of ropes when bent round rollers or cylinders. The results are as follows: 1. The resistance of ropes are directly proportional to the tensions to which they are subjected. 2. The resistance increases with some determinate power of the diameter, and is greatest in ropes that have been strongly twisted, or are coated with tar. 3. The resistances are inversely as the diameters of the cylinders about which the ropes are bent.

When a rope is wound more than once round a cylinder, the resistance increases in a geometrical progression. This principle is frequently applied in practice: thus, in arresting the progress of a vessel, a rope is wound round a post, and a very few turns is sufficient to overcome any force which the rope is capable of withstanding.

FRINGE MACHINE, SHAWL, invented by Milton D. Whipple, and used at the Bay State Mills, Lawrence, Mass., to twist the fringe of shawls, is a very successful, and as far as our knowledge extends, the only machine which has ever been applied for this purpose. We extract from the patentee's specifications the following description of it and its operations:—

The machine is so constructed as to imitate and perform the ordinary manual operations of dividing the yarns into proper quantities to form the *two single* strands, and then twisting the said strands separately in one direction, and afterwards bringing together and twisting them in opposite directions to form the fringe.

1851.

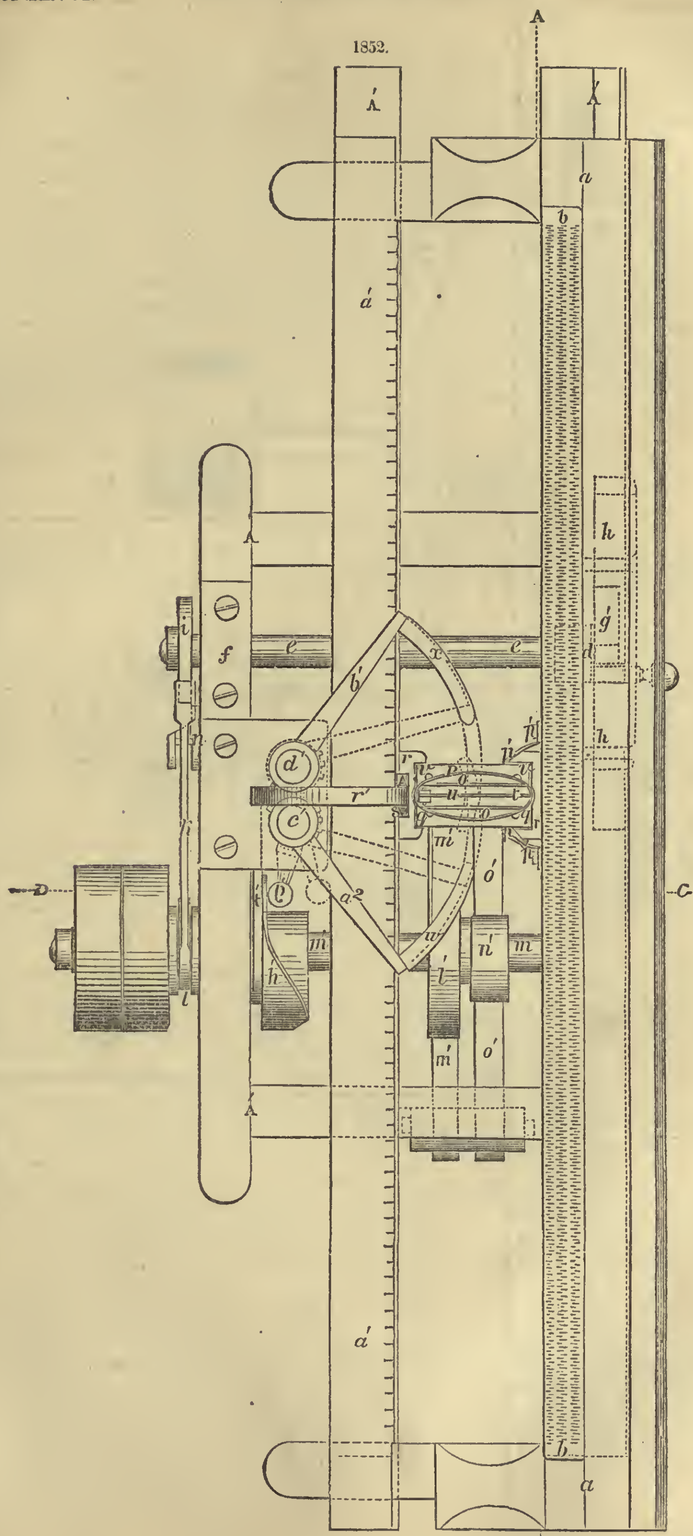


A′ A′ A′ A′ is the framework of the machine. *a a*, *a′ a′* is a stretching frame, having a strip of card teeth *b b*, Fig. 1852, on the stationary side of the frame, and a set of vertical points on the sliding bar *a′ a′*. The yarn from which the fringe is formed, having woven fabric on each side as usual, is stretched from said card teeth to said points, and the bar *a′ a′* is arranged so as to slide in and out to accommodate different lengths of fringes. This stretching frame is moved, or fed along by means of rack teeth formed on the under side of the bar *a a*, as shown at *c*, Fig. 1851, which engage with the teeth of a pinion *d*, on the shaft *e e*: said pinion being shown by dotted lines in Fig. 1852. This shaft has one of its bearings on the top of one side of the framework A′ A′ A′ A′, as shown at Fig. 1852; its other bearing being in a diagonal mortise *g* in the adjustable sliding bar *h h*, fitted in the opposite side of the framework, as shown by dotted lines in Fig. 1852, and in detail in Fig. 1854; so that by moving the said sliding bar in one or the other direction, the pinion may be thrown into or out of geer with the rack, and permit the stretching frame to be moved backwards, after twisting the fringe of one side of a shawl, for a new operation. During the operation of twisting, this frame is fed along accurately by means of a ratchet wheel *i*, on the shaft *l l*, the teeth of which are operated upon by the long pawl *k*, working on an eccentric *l*, fitted on the driving shaft *m m*, as shown in Fig. 1852, and by dotted lines in Fig. 1853.

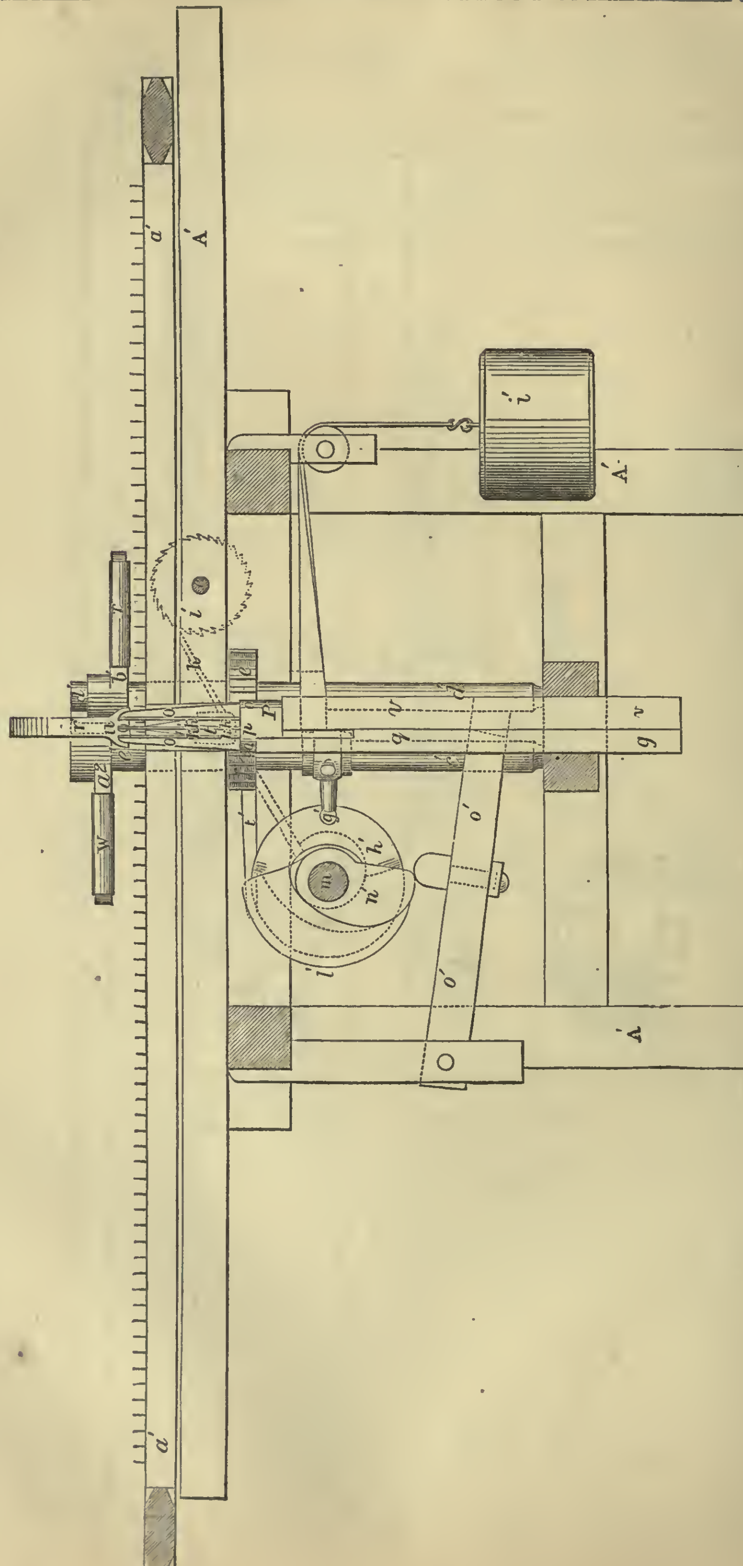
The feed motion is regulated by means of the adjustable forked supporter *n*, in which the pawl *k* rests, as shown in the drawings. By raising or lowering which supporter, the *fall* of the pawl *k*, when it is drawn backwards on the ratchet wheel *i*, by the action of the eccentric *l*, will be diminished or increased, as the case may be.

The machinery for dividing the yarns into proper quantities, to form the two single strands, as hereinbefore suggested, is as follows:—O O are two metallic triangular dividing plates, set at a proper interval apart on opposite sides of the elliptical ring *p p*, which ring is firmly fitted on the top of the vertical sliding beam *q q*, Figs. 1852 and 1853, arranged so as to slide up and down in proper guides *r r*, as shown in the drawings. The plates *o o* are curved transversely and vertically, so as to effectually separate the yarns, and have a rectangular slot or opening formed through each, as shown at Fig. 1851, for the passage of twisting fingers or rubbers, hereinafter described. The yarns embraced between these plates *o o* are subdivided or halved, for the purpose of forming two strands by means of the separator *t u*, having the same triangular contour as the plates *o o*, so as to enter, as they do, between the yarns at a mere point at first, and not get entangled with them. This separator is constructed in two parts, with sufficient space cut out to allow the passage of the rubbers or twisting fingers before referred to; both of said parts being connected to the top of the sliding beam V V, arranged side by side with that before referred to, and denoted by *q q*, and moving up and down in the same guides. One of said parts *t* of the separator is required to be fixed to said beam V V, and the other U is hinged, as shown by dotted lines in Fig. 1851, so as to turn from it, when in descending, it comes against the top of the upper twisting fingers;—the operation being similar to that of a pair of callipers or bent compasses used for measuring the diameter of cylinders, &c.

After the yarns have been divided, as above described, into two parcels for the formation of two strands, they are twisted by the curved twisting fingers or rubbers W X, which slide over each other,



1853.



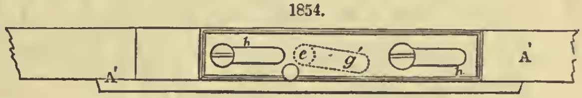
one above and the other below the yarns, as they pass through the openings in the dividing plates *o o* and separator *t u*.

These twisting fingers or rubbers should be clothed with leather, or some other suitable substance, sufficiently rough to turn and twist the yarns. They are connected to the ends to two arms $a^2 b^1$, projecting out when the machine is stationary, about at right angles to each other, from the vertical shafts $c' c'$, $d' d'$, and arranged with set-screws so as to be adjustable thereon.

The vertical shafts have proper bearings in the framework, and are connected in their movements, so as to turn together by the pinions $e' f'$ arranged on them as shown in the drawings. Said shafts are turned inwards, so as to bring the twisting fingers towards and over each other by the projecting stud *g*, inserted in the shaft $c' c'$, as shown in Fig. 1853, and abutting against the cam formed on the pulley h', on the driving shaft, as shown in Fig. 1852. The outward or back turning of said shafts $c' c'$, $d' d'$ is effected by the heavy counteracting weight i', connected to the shaft $d' d'$, as shown in Fig. 1853.

When the rubber or twisting fingers are passing over each other, twisting the yarns into two strands, the yarns are supported and lifted up in grooves in the upper side of flange pieces set on each side of the two parts *l u* of the separator, as shown at $k' k' k'$, &c., Fig. 1853, by dotted lines; and after the *two* strands are sufficiently twisted, the separator *t u* is drawn downwards, opening over the rubbers or twisting fingers in its descent; which descent is effected by the cam l' on the driving shaft *m m*, said cam operating on the treadle $m' m'$, the moving end of which is connected to the vertical sliding beam *v v*, on which the separator is fastened as above suggested.

1854.



When the separator is withdrawn after the two strands are twisted, as above explained, the rubbers or twisting fingers are moved outwards by the action of the weight as above described,—twisting the two strands together firmly, and forming the fringe as perfectly as it can be done by the most skilful operative.

The two dividing plates *o o* are then withdrawn by a cam n' on the driving shaft, said cam operating on the treadle $o' o'$, and vertical sliding beam *q q*, on which said plates are fixed, in the same manner as explained above, for the beam V V and cam and treadle by which *it* is operated. The stretching frame is now fed along, and the cams ceasing to act upon the treadles, the retroacting springs $p' p'$, $p' p'$, connected to the beams V V and *q q*, bring them, and with them the plates *o o* and separator *t u*, between the yarns for another operation.

While the yarns are being divided by the plates *o o* and separator, it is absolutely essential that they should be stretched transversely a little and held tight, in order to be easily divided, and that during the operation of twisting, this stretching and holding should be gradually relaxed. This result is attained by the long metallic hooked depresser and holder $q' r'$, which moves up and down in proper guides or mortises in the framework. The end r' of this depresser and holder falls on the yarn just behind the plates *o o* and separator *t u*, and immediately after said yarns have been divided, and presses them into a groove or bent plate formed at s', Figs. 1852 and 1851, to receive them. This bent depresser is operated by an arm t', which extends at right angles from one side of it, and rests on the face of a proper cam, formed to regulate its motion on the pulley h', as shown by dotted lines in Fig. 1853.

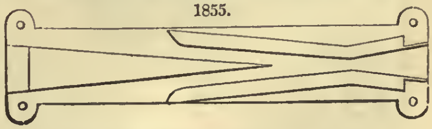
The patentee claims—First. Dividing the yarns into proper quantities for the formation of the two strands, by means of the dividing plates and separator.

Second. Twisting the *two* strands separately first, and then together, by means of the twisting fingers or rubbers, constructed and arranged so as to turn inwards and outwards over each other, one above and the other below the yarns.

Third. The peculiar construction and arrangement of the separator, so that it may open over the rubbers, and drop down just before the two strands are to be twisted together.

Fourth. A machine for twisting the fringes of shawls, &c., having a stretching frame, dividing plates, and separator, twisting fingers or rubbers combined, and operated successively, as hereinbefore specified and described.

1855.



FROG. The cast-iron crossing plate at the intersection of two lines of rails on a railroad. The intermediate point, being subject to great wear from its small surface and exposed position, is usually made of steel. This improvement was made the subject of a patent in 1837.

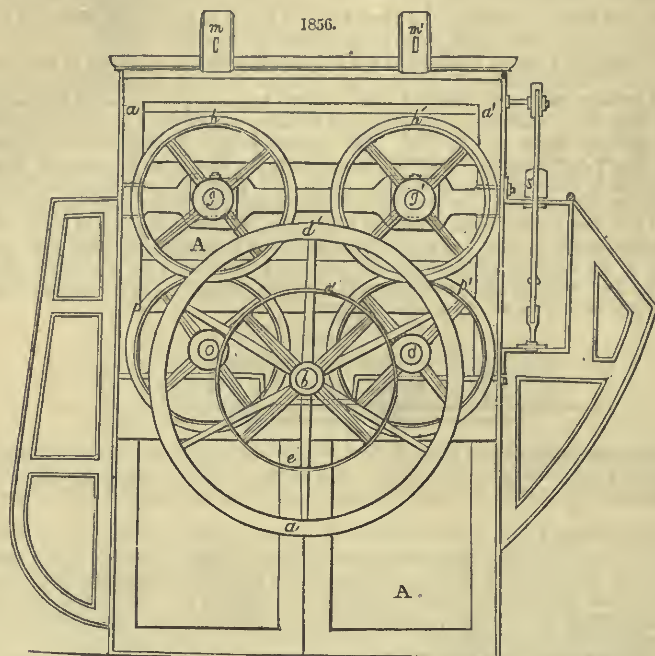
FULCRUM, in *mechanics*, the prop, support, or fixed point upon which a lever is sustained; and about which the lever is supposed to turn freely.

FULLING. A process by which woollen cloths are divested of the oil imbibed for the operation of carding, and the texture is at the same time rendered much closer, firmer, and stronger. This process, also called milling, was formerly entirely performed by the machine described under the head of Falling Mills, also called fulling stocks, Figs. 1861, 1862. The stocks, although still in extensive use, are fast being superseded by a superior class of machines, in which the cloth passes between squeezers, and is not subjected to heavy blows. By these machines the pressure can be regulated according to the quality and requirements of the fabric, the milling is more perfect, the power expended is less, and, not least, the disagreeable noise consequent on the use of stocks is avoided.

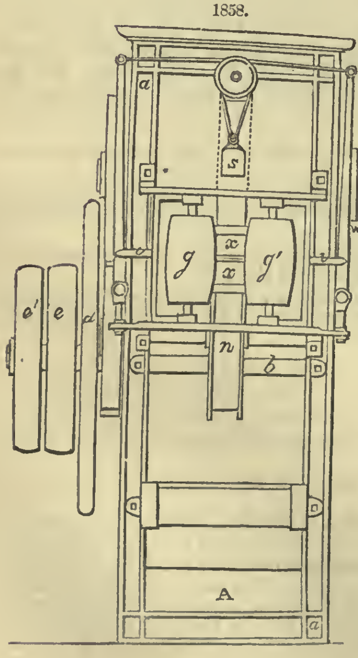
Figs. 1856, 1857, and 1858, represent different views of one of this class of machines. Fig. 1856 is a side elevation, Fig. 1857 a cross section, and Fig. 1858 a front end elevation of the machine It will be

perceived that the machine is composed of four cylinders $n\,n'\,f\,f'$ running horizontally, arranged in pairs one above the other, and two vertical cylinders $g\,g'$. Both horizontal and vertical cylinders are subjected to pressure: to the former it is applied by means of the weight movable on the arm of the

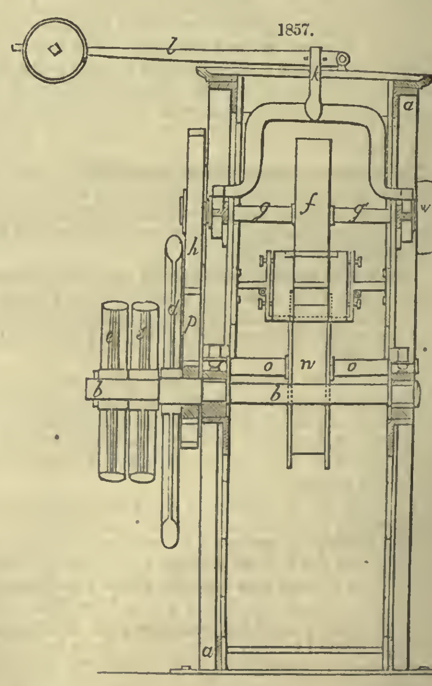
1856.



1858.



1857.



lever C, which forces down the yoke k on the boxes of the cylinder. The pressure is applied to the vertical cylinders by the variable weight s, through the levers w. In both cases the pressure to be exerted can be varied at pleasure.

The operation is as follows: one end of the cloth having been passed between the sets of horizontal and vertical cylinders, the two ends of the cloth are then attached together, so as to make an endless band. The machine is now set in motion by the pulley *e* on the shaft *b*, and the cloth continues to make the round between the cylinders or squeezers, falling in folds at the front of the machine, and drawn up again at the back till the washing and fulling is finished.

A rotary fulling-mill, still better than the preceding, is given in Figs. 1859 and 1860.

1859.

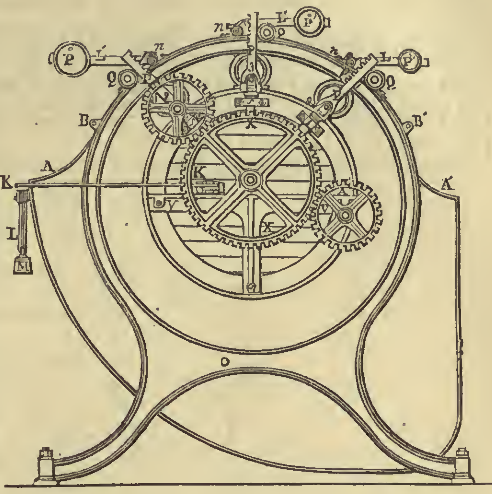


Fig. 1859 is the side elevation, and Fig. 1860 the longitudinal section, showing the interior arrangement.

A A is the main cylinder, (driven by a geer;) on either side are cheeks between which the small cylinders or rolls B^1 B^2 B^3 revolve, and between these rolls and the cylinder the cloth passes. C is the lower side or bottom of a trough which receives the cloth after it has passed the roll B^1, and down which it slides into the tub $d' d' d'$, curved, as shown in the drawings. D is the top of the trough, and is supported by the cross piece *d*; its upper extremity touches, but without friction, the surface of the roll B^1. E E are the grooved sides of the trough; their upper extremities are held by small iron straps attached to the frame by screws, and to E E by pins; the centre of the sides are fastened to small iron plates F F, which are supported on the standards G G, on which they turn freely; the standards themselves, attached to the plates H H, can turn on the pivots I I.

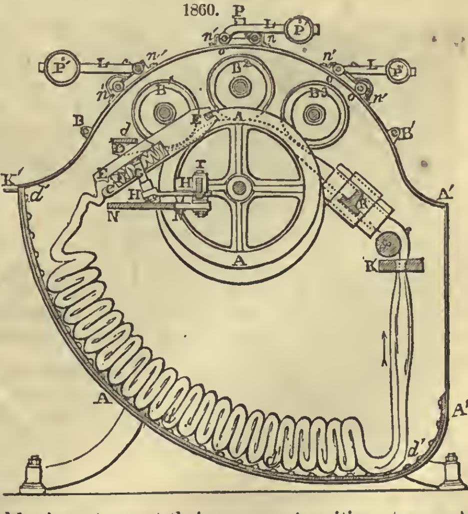
L is a cord attached to the ends of the levers K K, by which, through the aid of a pulley, the weight M tends to draw them together. N N, a cross piece attached to the frame and supporting the pivots I I, and guide plates C^1.

The journals 2, 3, 4, of the rolls B^1 B^2 B^3, run in bearings, inserted in the bars P P P, whose lower extremities are maintained in a position by the guide rings *s*, attached to the frame, which admits of a motion in the direction of their length; while at their upper extremities are racks into which play the toothed segments *p p p*, fixed in pairs on the shafts *n n n*.

P′ P′ P′, weights movable on the arms of the levers L′ L′ L′, whose fulcra are at *n n n*, and attached to the toothed segments *p p p*; by these weights the force with which the rolls B^1 B^2 B^3 press on the cylinder A is regulated. Q Q Q, guide rolls which keep the racks in geer with the segments.

R′, a plate perforated with an oval hole, through which the cloth is first passed, the effect of which is to straighten the folds; thence the cloth passes over a conducting roll S, through the short tube R, to the main cylinder; the tube R is supported by a cross plate attached to the frame.

1860.



The draft or drawing in of the cloth is occasioned by the pressure of the roll B^1 on the main cylinder, which cylinders are geered together by the pinion X′ and the geer X, on their respective shafts.

Operation of the machine.—The cloth is first passed through the aperture R′, over the roll S, through the tube R, to the groove or space between the cheeks of the main cylinder A, thence beneath the rolls B^3 B^2 B^1, and is delivered through the trough C D E at the back of the machine. The ends of the cloth are now fastened together, the mill is set in motion, and the operation is performed as in the preceding machine. The cloth is presented successively in a continuous round to the action of the squeezers till the fulling is finished.

It will be easily perceived that the effect of the passage of the cloth beneath the rolls B^3 B^2 B^1 is a stretching of the cloth in the direction of its length, which causes a thickening or fulling of the cloth in the width. The cloth should also undergo a compression or fulling lengthwise. This is effected by the sides E E of the trough C E D; these sides hold by iron straps at their upper extremities, at a constant distance, equal to that between the cheeks of the main cylinder, while their lower extremities, by means of the pivots G G and I I, admit of a lateral motion at these extremities. The weight M is made to act through the levers K K, which brings them together, and prevents the discharge of the cloth; the result

is that the cloth being still delivered by the roll B^1 is forced into the guide box till the pressure is sufficient to overcome that with which the two sides of the box are brought together by the weight M. The sides of the box then take a nearly parallel position. The cloth escapes gently and falls into the circular box or tub, which composes the lower part of the machine.

As by the weights P′ P′ P′ the pressure on the cylinders B^1 B^2 B^3 can be regulated, and consequently the fulling breadthways of the cloth, so by varying the weight M more or less resistance can be opposed to the discharge of the cloth, and by this means the fulling of the cloth lengthways can be increased or diminished.

A system of percussion has also been added to this machine. Small revolving or reciprocating beaters, making their blows on a fulling table, strike the cloth as it leaves the expanding trough.

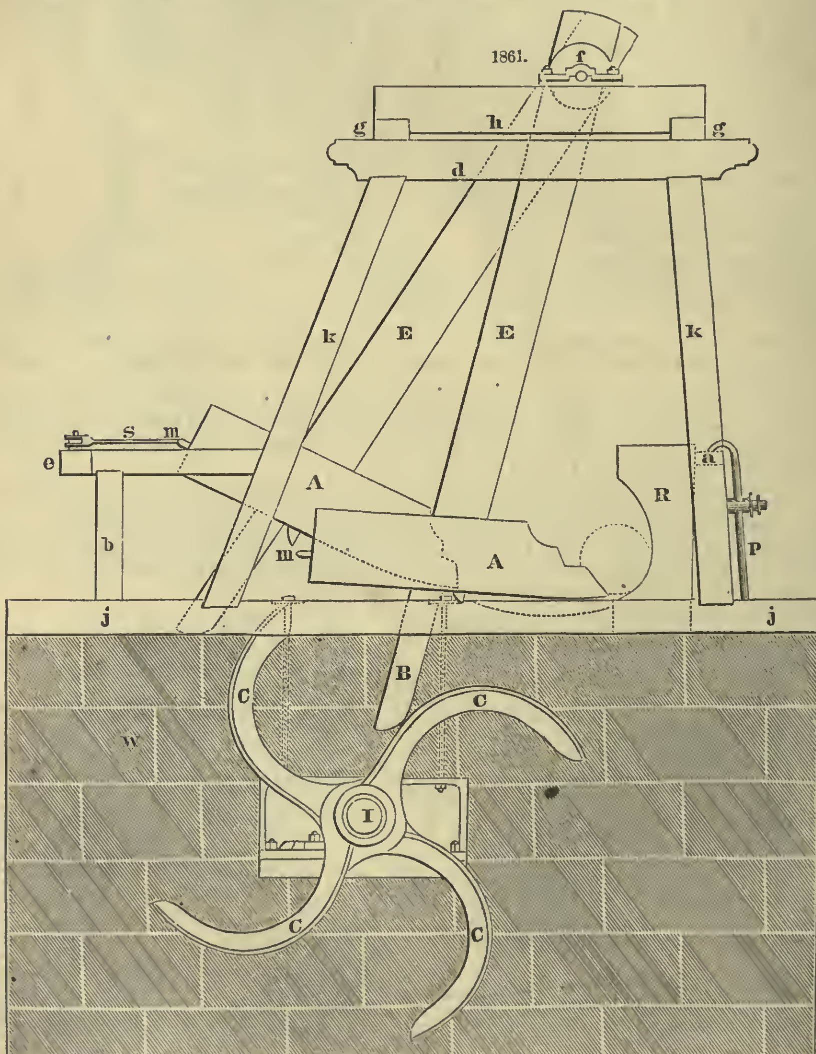
These machines have long been used in England and on the continent. They are now manufactured in this country, and where they have been adopted have given satisfaction.

FULLING-MILL FOR CLOTH. Fig. 1861 is a side elevation of the mill.

Fig. 1862 is an end elevation of the same.

The same parts are designated by the same letters of reference in both drawings

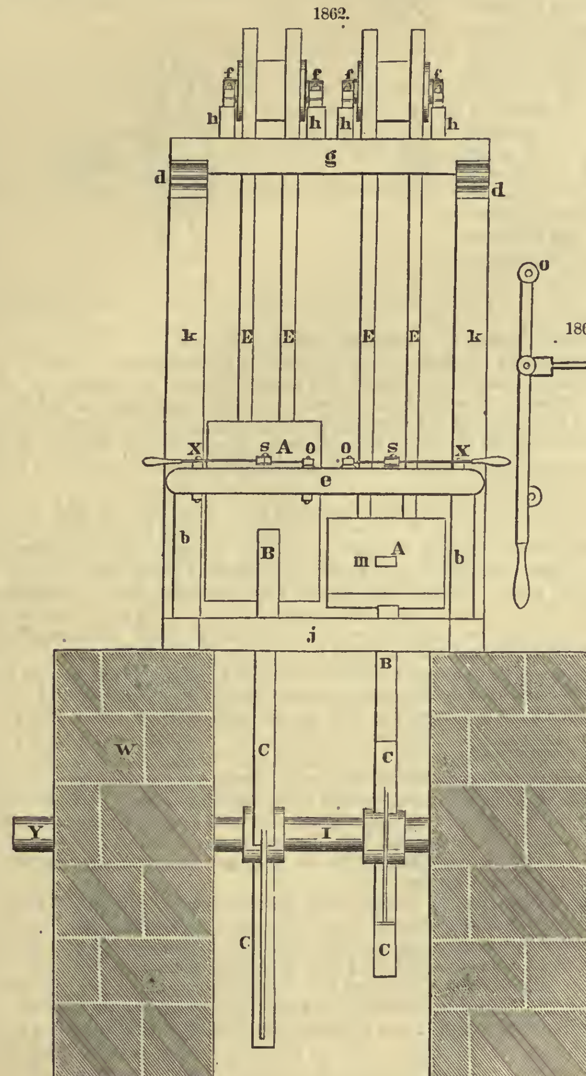
1861.



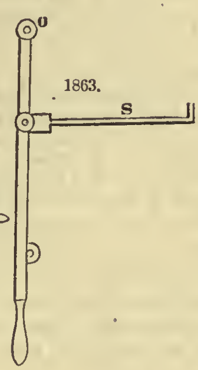
k k, the side framing of the machine, made of strong rectangular pieces of wood, connected together at the top by the cross beams *d d*, the cross rails *g g*, upon which the four pieces *h h h h* rest in positions parallel to *d d*, and at right angles to the rails *g g*. The use of the beams *h h h h* is, besides affording additional stiffness to the framing, to carry the four pedestals *f f f f*, in which are the working centres of the *feet*, or beaters A A. These are suspended by the *legs*, or pieces E E. From the under side of

the feet, the *lifters*, or wipers B B project; and by means of these the feet are continually thrown back by the two pairs of wipers C C C C, upon the common driving shaft I. The upright framing is secured at bottom by cross beams, into which the uprights *k k* are mortised; and these are bolted down usually to a solid foundation of stone. R is the *rowhead* of the receptacle or trough into which the cloth to be washed is put, and in which the beaters A A are suspended. The end R of this receptacle is formed of two or more blocks of wood, commonly oak, firmly jointed together, and is shaped internally into a parabolic curve, against which the cloth is pressed, by the beaters A A, alternately, during the operation of washing. By this means the cloth is continually, but slowly, being turned round by the action of the beaters upon it. Water is meantime supplied from the cistern *a*, which extends across the back of the framing, through a series of small holes pierced in the back of the trough R, and is let off through holes pierced in the bottom of the same. The centre *a* is filled from a well or other reservoir, by the pipe P

1862.



1863.

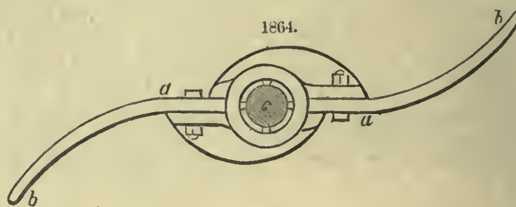


The feet A A, as above described, are worked by the double wipers C C C C on the wiper shaft I, these wipers being set pair and pair at right angles to each other, work the feet alternately; so that when one foot is being caught by its wiper, the other is at that moment being released. The feet thus rise and fall alternately, and make each two strokes during one revolution of the shaft I. Into the *heel* of each foot is screwed a staple of iron *m*, which receives a hook-catch *s*, jointed upon a lever, having its centre of motion at the stud *o*. The use of this arrangement is to keep up the feet when the cloth is being taken out of the trough. This lever and catch are represented separately by Fig. 1863.

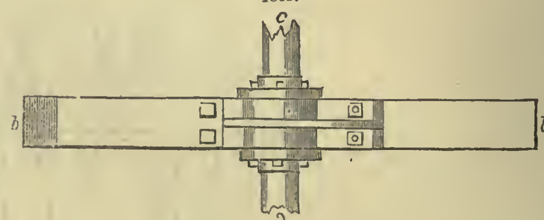
The wiper shaft is usually connected to one of the main shafts of the works by a friction coupling of

some kind, for the purpose of starting the machine with as little shock as possible. An efficient and simple coupling of this sort is, however, still a desideratum in practical mechanics.

1864.



1865.



In the machine from which these drawings were made, the wipers are of cast-iron. This, however, is not to be recommended, as the wipers are liable to break by concussion with the lifters B B; and, being cast pair and pair, in one piece, they are difficult and costly to replace. The most approved, and now the most common mode, is to cast strong centres which fit upon the shaft I, and to attach to these malleable iron wipers, which are not only less liable to fracture, but are also replaced with more facility in cases of failure from accident or decay. This arrangement is represented by the annexed wood-cuts, of which Fig. 1864 is an elevation, and Fig. 1865 a plan of a pair of the wipers. *c*, is the wiper shaft, upon which the cast-iron centre is keyed. This centre is cast with two flange pieces projecting in the plane of the axis, and strengthened by feathers on one side. These pieces are of the same breadth as the malleable iron arms *a b*, *a b*, which are to be bolted to them at *a a*.

FURNACE. An enclosed fireplace for generating great quantities of heat. Furnaces are of various forms, according to the purposes to which they are applied. In some cases it is intensity of heat that is required, as in the furnaces for smelting, casting, and forging metals, for descriptions of which see iron, metallurgy, &c. In other cases, a steady temperature is to be maintained, as in furnaces for the generation of steam. The first object in the erection of a furnace is to procure a sufficient supply of air for the support of the combustion of the fuel. In most of the former class of cases air is supplied by blowers, fans, &c.; in the latter, more commonly, but not entirely, the draft is created by high stacks of chimneys.

Flues.—To determine the area of the flue and chimney, it must be considered that 150·35 cubic feet of air are required for the combustion of 1 lb. of coal. Of this air 44·64 feet combine with the gases evolved from the coal, and 105·71 feet with the solid portion of the coal. The combination of the air and gases increases their volume 1-10th. The 44·64 feet thus become 49·104 feet. The sum of 105·35 with the carbon remains the same. The total product of the combustion (without considering the increase of volume resulting from raising the temperature) of 1 lb. of coal, is therefore $105·71 + 49·104 = 154·814$ cubic feet. Assuming the temperature of the furnace at 1000° Fahr., at which aëriform bodies are expanded to about three times their original bulk, the product will be $154·814 \times 3 = 464·442$ feet. Adopting the result of Dr. Ure's experiments, viz. that the products of combustion pass off at a velocity of 36 feet per second, the area to allow this quantity to pass off in an hour will be ·516 square inch. In a furnace in which 13 lbs. are burnt per hour on each square foot of grate, which is, according to Mr. Parkes, the average consumption throughout England, the minimum area over the bridge, or of the flue immediately behind the furnace, would be $·516 \times 13 = 6·709$ square inches. In practice, however, as a large surplus of air is always admitted, and the exactness supposed in this calculation cannot be secured, it is found advantageous to make the area 2 square inches instead of ·516. This gives 26 square inches of area over the bridge to every foot of grate where 13 lbs. of coal are consumed per hour to every foot of grate. As the temperature and bulk become gradually reduced in proportion to the distance from the fire, the area of the flue towards the chimney may be narrowed; but this should be done without awkward bends or sharp angles.

Proportions of heating, or flue surface to size of grate.—In boilers burning 13 lbs. per foot per hour, 18 superficial feet of heating surface to each foot of grate is a good proportion. This proportion omits the *bottom* surface of flat flues, and from $\frac{1}{2}$ to $\frac{1}{4}$ the surface in circular flues, as being inoperative.

Chimneys.—The area of the chimney should be $\frac{3}{4}$ that of the opening over the bridge, viz. $1\frac{1}{2}$ inch per lb. of coal consumed, or $19\frac{1}{2}$ inches for each foot of fire surface burning 13 lbs. per hour. But the whole diminution of flue should be made gradually, and not by any sudden contraction. A common rule is, that the minimum area of chimneys 24 to 30 yards high, is 400 square inches for each 20-horse power.

Chimney at St. Rollox's Chemical Works, Glasgow.

Total height from foundation	447	feet	6	inches.
Depth of foundation	15	"	0	"
Total height above surface	432	"	6	"
Diameter at base	45	"	0	"
" surface	40	"	0	"
" top	13	"	6	"

Thickness—bottom $3\frac{1}{2}$ bricks, at top $1\frac{1}{2}$.
Internal flue 260 feet high, and perfectly vertical.

Circular chimney at Friar's Grove Chemical Works, near Newcastle.

Extreme height			254 feet 9 inches.
Outside diameter at bottom of foundation			27 " 6 "
Inside diameter at bottom of foundation			14 " 3 "
Thickness	24 feet 8 inches		$3\frac{1}{2}$ bricks.
Thickness	107 "		3 "
Thickness	53 "		$2\frac{1}{2}$ "
Thickness	46 " 6 "		2 "
Stone top	6 "		

Uniform taper of $1\frac{1}{4}$ inch per yard.
Foundation, clay.

The temperature of the furnace and the surrounding flues.—It is a difficulty of no ordinary description to ascertain with sufficient accuracy the temperature of a furnace. In fact every fire and every furnace is continually changing its temperature, as well as the nature of the volatile products as they pass off during the process of combustion. When a furnace is charged with a fresh supply of fuel, its temperature is lowered, and that from two causes: first, by the absorption of heat which the cold fuel takes up when thrown upon the fire; and, secondly, by a rush of cold air through the open door of the furnace. Attempts have been made to remedy these evils by the aid of machinery and continuous firing, but taking the whole of the existing schemes into account, and bestowing upon them the most favorable consideration, it is questionable whether they are at all equal (either as regards efficiency or economy) to the usual way of working the fires by hand. Provided a class of careful men were trained to certain fixed and determined regulations, and paid in proportion to the saving effected.

The results of experiments obtained by Mr. Houldsworth's Pyrometer, indicating the mean temperature of the flues in a steam engine boiler, and the effects produced by the admission of air through regulated and permanent apparatus behind the bridge, show that in taking the quantity of water evaporated by 1 lb. of coal as the measure of economic value, the mean of nearly the whole experiments is as 100 to 112·65, or about $12\frac{1}{2}$ per cent. in favor of a regulated and continuous supply of air. Taking, however, the mean of some of the experiments, and comparing it with some of the others, it will be observed that a much higher duty is obtained; and having accomplished a maximum, there appears no reason for doubting why it should not be continued, and still further advantages secured by a judicious arrangement of the furnace for the admission of oxygen to the uninflamed gases, which under other circumstances would make their escape into the atmosphere unconsumed. In furnishing this supply it is not absolutely necessary to administer it immediately behind the bridge, as the same quantity of air taken through the grate bars, or in at the furnace doors, would nearly effect the same purpose, not only as regards the quantity of heat evolved, but also as respects the transparency of the gases and the consequent disappearance of smoke.

Mr. Houldsworth estimates the advantages gained by the admission of air (when properly regulated) at 35 per cent., and when passed through a fixed aperture of 43 square inches, at 34 per cent. This is a near approximation to the mean of five experiments, which gives $33\frac{1}{2}$ per cent., which probably approaches as near the maximum as can be expected under all the changes and vicissitudes which take place in general practice.

In order to ensure economy and effect in the combustion of fuel, a large and copious supply of air must be admitted to the furnace, and that in the ratio of 10 volumes of air to 1 of coal gas; *when that quantity is at its maximum or in excess, there is no smoke; when it is different, smoke is invariably present.* Now perfect combustion is the *prevention of smoke.* It therefore follows, that in order to render the residue of the products of combustion transparent, or "*smokeless*," a supply of air amounting to ten times that of the gases evolved must be admitted. Should it exceed that quantity the effect will not be smoke, but an additional expenditure of fuel to supply the loss of heat which this excess of air would require for absorption, rarefaction, &c. Hence the necessity which exists for power to regulate the admission, if not the exact, at least an approximate quantity of air. On the other hand, should the supply be deficient in quantity, (which is often the case,) a dense volume of smoke is then visible, accompanied with all the defects and annoyances of imperfect combustion.

It is difficult to determine the exact quantities of gas evolved from every description of fuel, and probably equally so to supply its equivalent of air; but in order to attain certainty in this respect, let the openings be made sufficiently large, and by a little attention to the quality of the fuel and quantity of air required for its combustion, the apertures may be contracted till such time as a mean average and a close approximation to the maximum effect are obtained.

The concentration of heat is a consideration of much importance in the economy of the steam engine and the industrial arts; and much depends upon its preservation.

For this purpose we should recommend the flues and furnaces of boilers, and other fires, to be closely encased with good building material adapted for the retention of heat, and all steam boilers to be well covered and clothed, so as to prevent (as much as possible) the escape of heat in that direction; and for steam engines, that all the steam pipes, cylinders, &c., should be closely enveloped in a thick coating of felt, canvas, or wood, and afterwards well painted. These precautions being taken, the effects will soon become visible in a saving of 15 to 20 per cent. of fuel.

The above extracts are from Reports on English practice, and have their application more particularly to furnaces using bituminous coal.

On the principle above enunciated, that in the combustion of fuel a certain quantity of air is requisite, and that either an excess or deficiency is prejudicial to proper and economic combustion, Messrs. Barron and Brothers, of New York, have constructed their portable blast furnace.

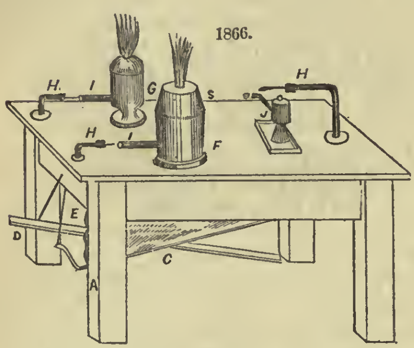
The furnace is so arranged that all metals are melted by it at a less expense of time and fuel than by any other furnace.

Gold, silver, and copper, can be melted by it in less than ten minutes. No. 1 size will melt from 4 to 12 ounces of gold with less than one quart of coal; No. 2 will melt from 50 to 100 ounces with two quarts of coal; Nos. 3 and 4 from 100 to 500 ounces.

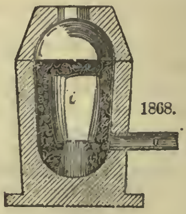
Fig. 1866 represents not only the furnace, but also an operating table, to which is attached blow-pipes, bellows, &c.; it forms a convenient stand for the furnace, but is not necessarily connected with it.

Fig. 1867 represents a contrivance for supplying it with air by a small pair of bellows resting on a table. P is the bellows, R a block for the support of the nose of the bellows, to keep it at a convenient height and distance with respect to the air-pipe O. It will be seen that as the air comes out of the bellows in a condensed form, by the time it reaches O *it begins to expand*, and the heat it abstracts by that action is drawn from the tube O, and not from the fire in the furnace, at the same time the warm and expanded state in which it reaches the fire, causes it to be equally diffused through the burning material, and produces throughout an effective intensity of heat.

1866.



1868.



1867.

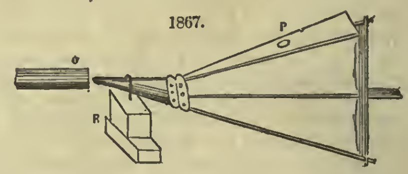


Fig. 1868 exhibits a section of the furnace. K is an inverted crucible on which another crucible L is placed, surrounded by fuel. O is the tube through which the air is supplied.

The operating table, Fig. 1866, is not necessarily connected with the furnace—nevertheless its conveniences deserve the consideration of the artisan. It is a table covered with a sheet-iron top, having holes through which are brought three blow-pipes H H H, supplied with air by the bellows C underneath, which is furnished with a wind chest whereby a steady stream of air is sustained. Before the blow-pipes you can place either furnaces F or G, or spirit lamp J, as may be required. The table and furnace and spirit lamp supply all that is needful to render the melting and soldering of metals *safe* as well as *easy*.

FURNACE, *Reverberatory*. Figs. 1869 to 1872. These Figs. represent the form and dimensions of a most important adjunct to Nasmyth's steam hammer, which, with slight modifications, will be found applicable in many stages of the iron manufacture.

A A, the hearth and building upon which the furnace is erected. It is lined throughout with fire-bricks, and the hearth is formed at a slight inclination, so that the flame and heat may more effectually react from the arched roof upon the work placed on it.

B B, the roof and sides of the furnace, also formed of fire-bricks. The roof is arched throughout its entire length, in order that the heat may be reflected and concentrated upon the work placed on the hearth.

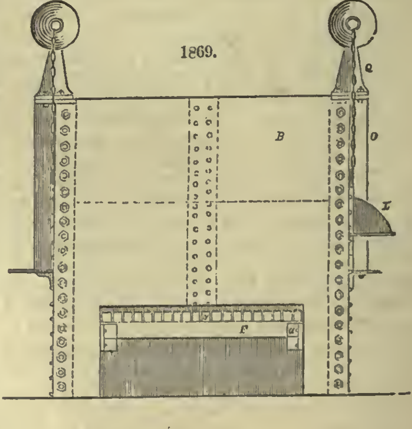
C C, the sheet-iron sides of the furnace, by which the brick-work is secured and retained in its proper form.

D D, the end plates for binding the side plates together. Instead of being riveted to the side plates, they are secured by bolts and nuts, so that the whole structure may be easily taken asunder when it is necessary to rebuild the furnace.

E, the ash-pit.

F F, cross bearers of wrought-iron for supporting the furnace bars *a a a*. The ends of the bearers rest in small cast-iron brackets *b b*, secured to the sides of the ash-pit.

1869.



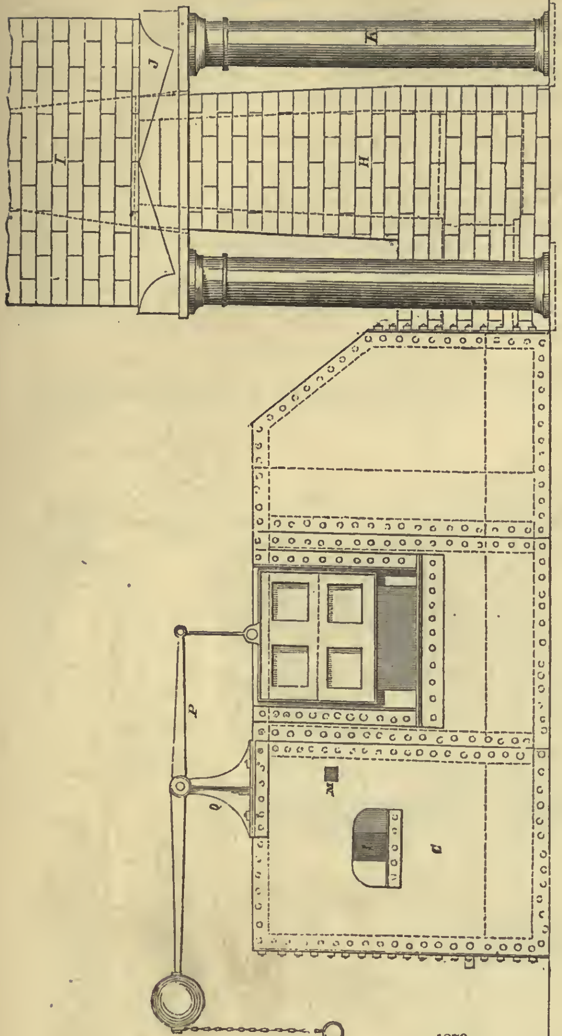
G, the passage to the chimney, formed in continuation of the arch of the roof.

H H, the chimney, constructed internally and throughout its entire height, of fire-bricks.

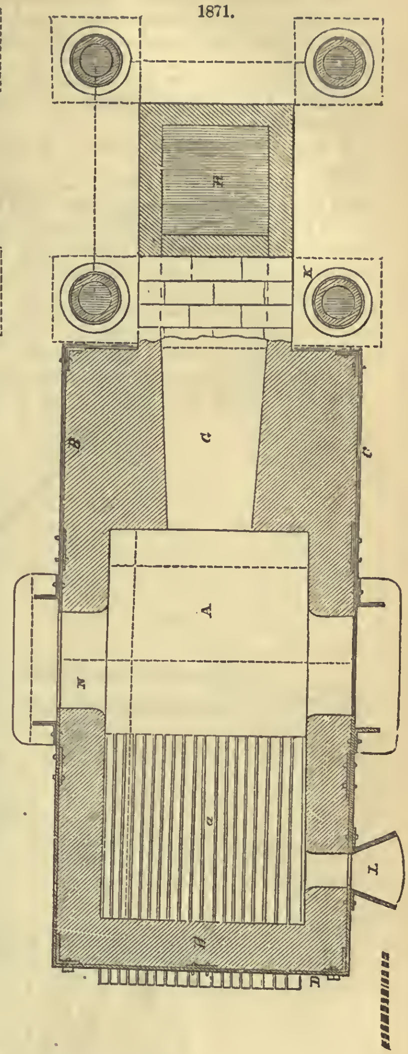
I I, corner pieces of ordinary bricks built upon the angles of the interior chimney for the purpose of giving stability to the whole structure, which is further bound together by bolts *d d d* passing through the small cast-iron pieces *c c c*.

J J, cast-iron sole plate for supporting the brick work of the chimney, and which is itself supported by

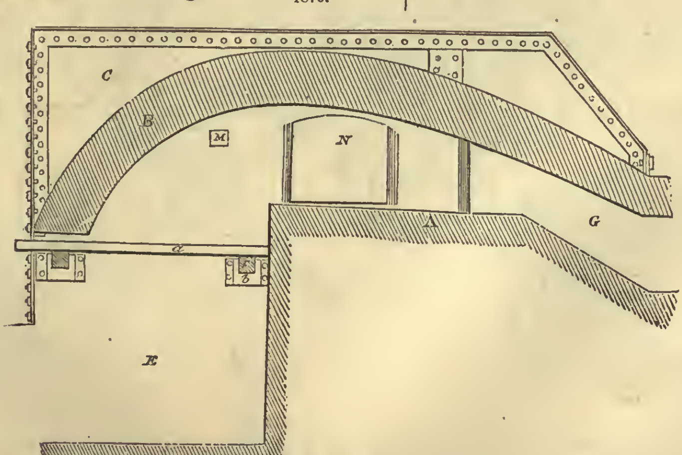
1872.



1871.



1870.



K K, four strong cast-iron columns resting on a solid foundation of mason-work.

L, the stoke-hole, through which the fuel is introduced into the furnace. The mouth of this stoke-hole is so constructed as to admit of its being stopped with a piece of coal when the furnace is in full operation.

M, a small square aperture in the side of the furnace by which the attendant is enabled to inspect the state of the furnace without interrupting the progress of the work. It may be stopped with a single brick.

N N, the main openings into the furnace, through which the shaft or other work to be heated is passed.

O, the sliding door by which the aperture N is guarded. It consists of a square cast-iron frame, lined internally with fire-bricks, and fitted to slide vertically between guides of angle iron.

P P, levers working upon the cast-iron brackets Q Q, surmounting the furnace. They are loaded at the outer ends with counter-weights, and attached by short connecting rods to the doors O O, so as to enable the stoker to raise or lower the latter with the utmost facility.

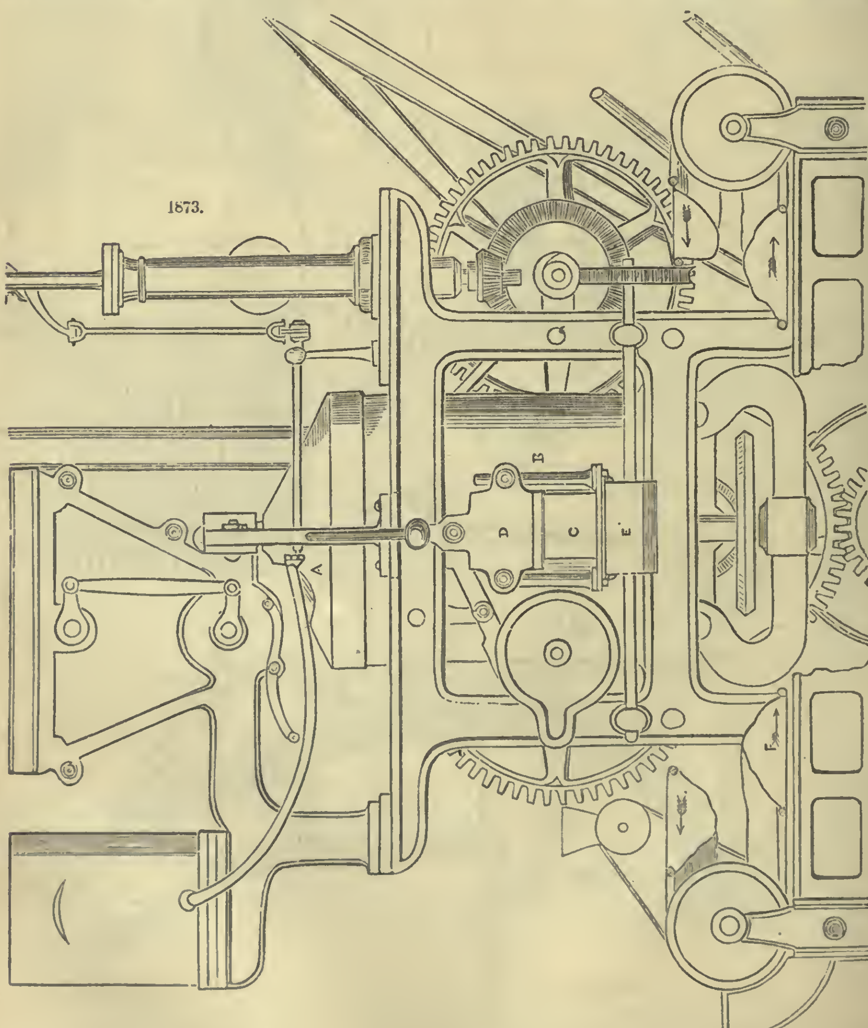
R, a register or damper surmounting the chimney, for the purpose of regulating the draught of the furnace. It is brought within the command of the attendant workman by means of a long chain or wire *e e*, depending from the lever upon which it is hung.

FURNACES, *Hot-air*. See WARMING.

FURNACE. *Ovens, and machinery used for making bread.*

Fig. 1873 represents a front view of a bread machine recently erected in Glasgow, under Messrs.

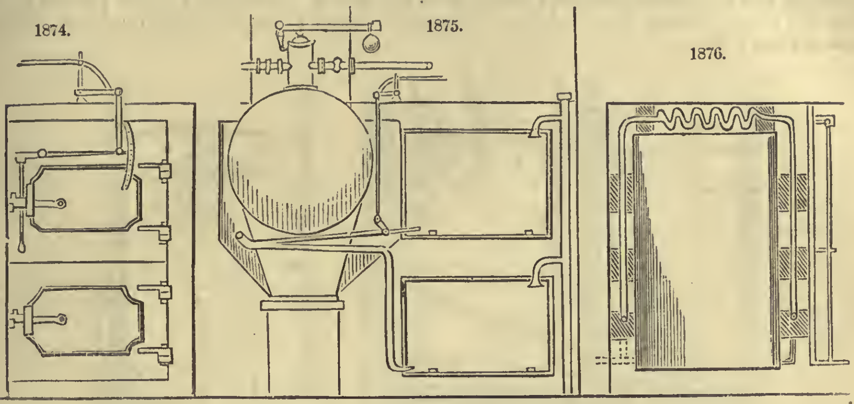
1873.



Robinson and Lee's patent. One ton and a half of loaf bread, or a ton of biscuit, is produced by this invention hourly, without the intervention of human labor in any stage, although the machine itself

occupies less than a square yard of space. It is well known that the process of setting the sponge, in the common mode of bread-making, consumes a considerable period of time, and occasions great waste of the nutritive qualities of the flour. The patentees of this machine state that they prevent both these losses by the use of carbonated water, which can be very cheaply prepared; but the machine is equally adopted for those who prefer yeast in the manufacture of bread. By a very simple but ingenious pro-

1874. 1875. 1876.

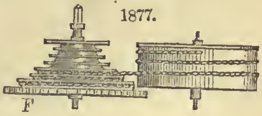


cess, the liquid and flour are made to fall together in due proportions upon a cone A, which partially mixes and conveys them into the kneading trough B, whence the dough is forced out at an aperture C, and cut off by an eccentric knife D in the precise quantities wished. Falling upon a roller E, these pieces are carried by the same machinery through a moulding tube F, and thence into the oven, Figs. 1874 and 1875; where the steam by which the whole concern has been kept moving is, after passing through a red-hot coiled pipe in the furnace, Fig. 1876, applied in direct contact with the batch, and produces a very pure crust. The heat, too, is both indicated and regulated by a self acting pyrometer, whereby the baker can assure his batch against being either burned or slack baked.

FUSE, *for blasting.* In this country the "safety fuse" is most generally employed. It consists of a cotton tube filled with powder, wound with tarred thread or twine, and a coat of tar is then applied on the outside. The whole forms a cord of about 3-16th of an inch in diameter, so hard and firm in its texture as to resist the action of tamping. It is impervious to water, and burns regularly at a rate of about 2½ feet per minute. An improvement on the safety fuse has been patented, namely, the introduction of a thread in the centre of powder to ensure its continuity, and prevent any chance of a miss-fire. Powder hose is sometimes used in England, made of strips of linen or cotton cloth sown together, and filled with powder; these, when full, vary from half inch to an inch in diameter. The hose is inclosed between two hollowed strips of wood, where it would not be damaged by the tamping, and a piece of port fire is attached to the match end, to afford time to the blaster to escape before the charge is exploded.

FUSEE, in *clock-work*, is a mechanical contrivance for equalizing the power of the main-spring of a watch; for as the action of a spring varies with its distance from the quiescent position, the power derived from the force of a spring requires to be modified according to the circumstances, before it can become a proper substitute for a uniform weight, which is what it is intended to supply. In order, therefore, to correct this irregular action of the spring, the fusee F, Fig. 1877, on which the chain or catgut acts, is made somewhat conical, so that its radius at every point may correspond with the strength of the spring, being greater and greater as the action of the spring becomes more and more weakened by unbending. If the action of the spring diminished equally, the fusee would then require a perfect conical figure; but the decrease of the power of the spring does not follow that uniform law, and, in consequence, the figure of the fusee deviates from the form which it would otherwise take, and becomes a solid, generated by the revolution of an equilateral hyperbola about its asymptote. See Watches.

1877.



FUSIBLE METAL, consisting of 8 parts of bismuth, 5 of lead, and 3 of tin; it melts at the heat of boiling water, or 212° Fahr. By the addition of a very little mercury it becomes still more fusible, and is used for certain anatomical injections, and for the filling of carious teeth.

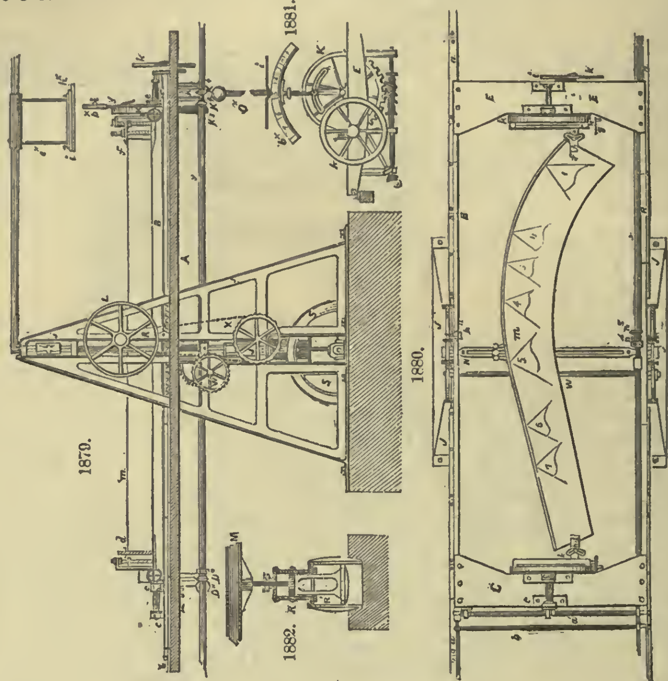
FUTTOCK, *or ship timber converting machine.* We are glad to have it in our power to lay before our readers a set of engravings of the machinery of Mr. J. Webster Cochran, of New York, for sawing Futtocks and other timber used in ship building. We exhibit this machine not merely as described in his English specifications, but as it has been since improved in many important particulars. We shall take the specification for the groundwork of our description, and deviate from it only when this may be rendered necessary by the modifications introduced by the inventor.

Fig 1878 is a front or end elevation of the machine. Fig. 1879 is a side elevation. Fig. 1880 a plan. Fig. 1881 is a transverse section through the chuck-plate wheel; and Fig. 1882 is a detached view of part of the steam machinery.

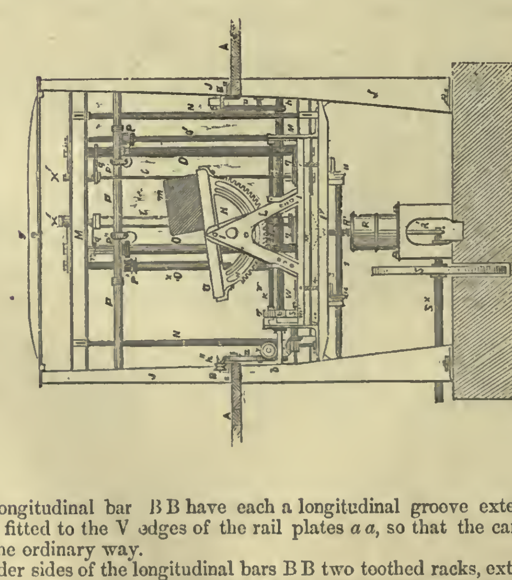
A A A are the stationary framing or sills upon which the sliding carriage of the mill is mounted. They are firmly fixed, in the usual way, upon the ground, or upon masonry in the building in which the mill is intended to be placed. Two longitudinal rail plates *a a*, of the usual description, having V edges

on their upper sides, are securely fixed upon the horizontal longitudinal sills or beams of the framing, and upon the V edges of these rail plates the sliding carriage moves in the usual way, for the purpose of advancing any piece of wood which it may carry up to the saw or saws, in order that it may be cut into the required shape or shapes.

The sliding carriage in or upon which is to be placed any log or piece of wood intended to be cut, consists of two longitudinal bars B B, (which form the base of the carriage,) placed parallel to each other, and braced together into the form of a rectangular frame by the transverse rod *b*, and the head block or plate C C.



1879. 1880. 1881. 1882.



1878.

The under sides of the longitudinal bar B B have each a longitudinal groove extending the whole length of the carriage, and fitted to the V edges of the rail plates *a a*, so that the carriage may slide easily and securely along the ordinary way.

There are also on the under sides of the longitudinal bars B B two toothed racks, extending along the whole length of the carriage. These racks are placed parallel with the grooves before mentioned, and so that a pair of pinions *h h′* may, when a piece of timber is to be cut, move the carriage along upon the rail plates *a a*, by means of trains of wheels connected with the pinions. And when the piece of

timber has been cut, the machinery may be thrown out of geer, and the sliding carriage moved back by any of several well known means.

The sliding carriage is kept down in its proper position by two friction rollers $h^2 h^2$, one on each side, which have their edges fitted to the V rails which run along the upper sides of the sliding carriage, as after mentioned. Each of these rollers is attached to the inside of one of the standards or fender posts J J, (within which the sawgate works immediately above the sliding carriage.)

Upon the head block C C is mounted the poppet head *c c*, which is made capable of being moved laterally in a dovetailed groove, for the purposes of adjustment. In this poppet head is an axle, which carries the chuck plate D, and this chuck plate is made capable of turning freely upon its axis. This chuck plate has a dovetailed groove extending across the face of it, and having fitted into it the foot of the jaws or clips *d d*, the lower of which is made fixed and the other movable.

The movable jaw is kept in its place by two bolts, and by a nut; upon one of these bolts it may be screwed towards the other jaw, for the purpose of holding one end of a log of wood or piece of timber firmly in the carriage. And the lower or fixed jaw, or clip, must be mounted in such a way that the inner surface will at all times coincide with an imaginary line drawn across the face of the chuck plate D, and through the centre of the axis thereof. These jaws or clips may, by means of the screw shaft *g*, be moved across the face of the chuck plate in either direction, as may be required for the purpose of balancing a log or piece of wood, which is to be held between the chuck plates whilst it is being cut.

The head block E E is mounted upon the side bars B B of the sliding carriage. Along the tops of the side bars B B are V edges, and under and across the ends of the head block E E, are grooves to receive the last mentioned V edges, so that the head block E E, when placed across the sliding carriage, with its grooves upon the same V edges, may slide easily along, above, or upon the tops of the sliding carriage, in the direction which may be required for the purpose of adjustment, according to the length of the log or piece of timber to be cut.

The head block E E has motion given to it (along the carriage) by means of a pair of pinions, which are fixed upon a transverse shaft under the head block, and which serve the purpose of keeping the head block down in its proper position on the carriage. This transverse shaft forms the axis of each of the last mentioned pinions, and the bearings of the shaft (in which it is made to turn by means of a hand wheel, handle, or other convenient means) are fastened to the under side of the head block E E. The last mentioned pinions are placed in such a position that the teeth of these pinions take into the teeth of the toothed rack, which is placed upon the under sides of the longitudinal bars B B, as before mentioned; and as the pinions are turned round in the one direction or the other, the head block E E will be moved towards the one end of the sliding frame or the other.

Upon the head block E E is mounted a puppet head *e e*, which is made capable of being moved laterally in a dovetailed groove, for the purpose of adjustment, in like manner as the poppet head *c c*, on the head block C C. In this poppet head *e e* is an axle, which carries a toothed wheel K, to which is attached the chuck plate F, and this wheel with the chuck plate is made capable of turning upon its axis. This chuck plate has a dovetailed groove extending across the face of it, and having fitted into it the foot of the adjustable jaws or clips *f f*, which are intended to hold the other end of the log of wood or piece of timber placed in the sliding carriage to be cut. These jaws or clips are constructed and mounted in or upon the chuck plate F, in like manner as the jaws or clips *d d*, which are mounted in or upon the chuck plate D D.

The fixed and movable jaws of the clips may be made also with quadrant slots, in order that the movable jaw or clip may be capable of being turned to one side or the other, so as the better to grasp and hold the end of any irregularly formed end of a piece of timber.

In each of these figures there is represented a log or piece of timber *m m*, held in the sliding carriage by means of the jaws or clips, showing its appearance after it has been submitted to the action of the saws, and had two of its sides cut so as to make it externally of the required shape.

To place a log or piece of timber in the sliding carriage in a proper position for being cut, one end of it must be placed between the jaws or clips of the chuck plate D, which is mounted on the fixed head block *c c*, and the movable head block E E being then moved to a proper position for enabling the jaws or clips of the chuck plate F to receive the other end of the log or piece of timber, that end of the log or piece must then be placed between those joints or clips. The nut of the screw bolt of each pair of jaws or clips is then to be turned so as to bring the movable jaw or clip down upon the log and hold it securely.

In the place of the roller, which is ordinarily used in sawing mills or machines, for the purposes of supporting a log or piece of wood, at an intermediate point between the ends, and near to the saws of the mill, an oscillating cylindrical roller is used, or a roller having its axis capable of being deflected from a horizontal position.

This roller support is placed at a position as near as conveniently may be to the saws of the mill, and in front thereof, and must be independent of, and separate from, but within the frame of the sliding carriage. This roller, and the machinery connected therewith, may be supported by any framing, or other convenient means, upon the ground, or in connection with the stationary framing of the mill.

G, Fig. 1878, represents a cylindrical iron roller mounted upon an axle in an oscillating segment piece H. This segment piece is supported by an axle, stud, or trunnion, at each side thereof, which is mounted in the frame H; these axle studs being placed at right angles with the axle of the roller.

The segment piece H has the semicircular edge thereof toothed, so as to take into the threads of the endless screw L, and the segment piece is held down by a quadrant slot in the segment piece, and working on a pin or pins in the frame I, so as to allow of the oscillation of the segment piece for the purpose of varying the deflection of the axis of the roller G, in any manner which may be required.

The quadrant slot is to be made of a sufficient length to allow of the deflection of the roller support to any extent which may be requisite.

Each side of the frame I I is fitted within two upright supporters *i** i***, the sides of the frames

having longitudinal grooves or slots to receive the ends of pins to be driven through the uprights into the grooves, so as to keep the frame I I securely within its two uprights, and yet allow it to be varied or depressed as may be required.

The frame I I is supported by two jack screws 4, 4, which are threaded into the lower part of the frame I I, and the shoulders of these screws work against a stationary rail or bar I*, which is firmly fixed to the stationary framing, or foundation of the mill.

The lower ends of the jack screws are furnished with bevel wheels 3, 3, which respectively take into two bevel wheels 2, 2; and the bevel wheels 2, 2, are fixed upon a transverse shaft 1, which may be turned by a handle or other convenient means. By turning the shaft 1, the bevel wheels will be put in motion and the jack screws turned, and as these screws are turned the one way or the other, the frame I I may be raised or lowered as may be desired. By these means the frame I I, and the roller G, may be lowered so as to remove the roller G out of the way when desirable so to do; and by raising the frame I I and the roller G, the roller may be elevated in such a way as to form an intermediate support to a log or piece of wood whilst the saws are cutting it.

If the pieces of wood intended to be cut in a mill, should happen to be of such a description that they will not be held sufficiently steady during the operation of sawing by one intermediate roller support, such as before described, the same mill may be constructed with an additional oscillating roller support, (similar to that before described,) and capable of being raised and lowered as before mentioned, and such additional oscillating roller support may be placed behind the vertical saws, or in any other position which may be found desirable, for the farther or better supporting the pieces of wood to be cut in the mill.

Pieces of wood for shipbuilding, and for various other purposes, frequently require to be cut into irregular shapes, and for the purpose of preparing such pieces of wood of the desired shapes, it is often necessary that one or more of the surfaces thereof should be cut with a varying bevel or surface, or with a surface cut in a twisting or winding manner, the bevel or direction of a cut, or cuts, constantly varying, either regularly or irregularly, in one or more than one direction as the cutting proceeds.

The saws of a vertical saw-mill cannot, as such mills are usually constructed, be moved out of their perpendicular position, to either the one side or the other for the purpose of varying the bevel or surface of a log, or piece of timber, which they are cutting.

This object may, however, be attained by gradually turning a log, or piece of timber, which has been placed in a mill to be cut in the requisite direction, or directions, as the operation of sawing proceeds.

For the purpose of being enabled to turn a log, or piece of wood, during the cutting thereof, this improved sawing machine is constructed with revolving chuck plates and oscillating segment pieces, with roller support, or supports, as before described.

These chucks and the intermediate roller support, or supports, may be turned in the manner required by the hand, or by any convenient machinery effecting that object, such as that now about to be described.

The teeth of the wheel K, behind the chuck plate F, take into an endless screw L, as shown in Fig. 1881, which is fixed upon a transverse shaft K^1, and in like manner the teeth of the oscillating segment piece H take into the endless screw L^2. The chuck plate D may, if it should be thought desirable, be furnished with a rim of teeth taking into an endless screw in like manner; but a machine will work sufficiently well for all ordinary purposes without this addition to the machine as represented in the figures.

When a log or piece of wood has been placed with its ends in the jaws or clips of the turning chuck plates, the roller support G must be raised until the upper surface thereof comes in contact with the log; and the mill or machinery must be put into geer in such a way that the direction and degree of the inclination (if any) of the axis of the roller support G to the horizon must at all times be the same as that (if any) of the face of the fixed jaw or clip of the chuck plate F.

The chuck plate F, and the segment piece H, must at all times be turned together in the same direction, and in the same degree, or with the same speed; and the chuck plate D being left free to turn upon its axis, will be turned as the log or piece of wood may be turned.

Upon the end of the driving shaft K^1, of the endless screw taking into the teeth of the chuck wheel K, is fixed a bevel wheel K^3, taking into another bevel wheel K^4 upon the driving shaft *y*, which last mentioned wheel is prevented from turning upon the shaft by means of a feather or key in the boss of the wheel, which takes into a groove along one side of the shaft *y*. For the purpose of preventing the shaft *y* from springing, and also for keeping the bevel wheel K^4 in geer with the other bevel wheel K^3, a collar K^5 is fitted upon the boss of the bevel wheel K^4, (within which collar the boss of the wheel turns freely;) and the collar is attached by its arm to the under side of the head block E.

The boss of the wheel K^4 is kept in its place within the collar K^5 by a narrow collar fastened upon the outer end of the boss by a set screw.

And as the head block E on the sliding carriage, with the same head block, is moved along in either direction, the bevel wheel K^4 which the shaft *y* turns will be moved along at the same time, and kept in geer with the other bevel wheel K^3, with which it is intended to work.

The driving shaft K^2 has its bearings in the movable frame I I, with which it must rise and fall. One end of this driving shaft passes through its bearings in one side of the frame I I, and through the next adjoining upright *i***, in which a slot is cut, so that the shaft K^2 may pass up and down within the slot, as the frame I I rises and falls. The shaft K^2 has its outer end fitted into a hole or bush in the collar upon the boss of the wheel, so that the collar must be raised or lowered in like manner as the end of the axle which works within the same bush or hole.

Upon or near to the end of the shaft K^2, which is next to the collar, is fixed a bevel wheel, which takes into another similar bevel wheel. The bevel wheel, with its long boss below it, is placed upon an upright driving shaft, which has a groove or key-way cut along one side of it, to receive a feather placed in the inside of the boss of the bevel wheel, which is made to move freely up and down within the groove.

The bevel wheel and its boss move freely up and down upon the shaft, and the boss of the bevel wheel, which turns freely within the collar, is kept securely within that collar by means of a narrow collar fastened upon the end of the boss by a set screw, in the usual manner. The bevel wheels are thus at all times kept in geer with each other.

The shaft has its bearings at the foot in a socket or step, and at the top in a bracket, as shown.

Upon the top of the shaft is fixed a bevel wheel, which takes into another bevel wheel fixed upon the shaft y.

The boss of the bevel wheel n^5 is made to move in a bearing or bush at one end of a bracket or arm, within which the boss turns freely, and the bracket or arm is fixed to the frame I*, and by these means the shaft y is kept steady, and in its proper position whilst in motion.

When the driving shaft y is left at rest, the movable chuck plate F, and the segment piece H, with the roller G, will also be left in a state of rest; that is, they will not be turned either to one side or the other of the machine. And when it is unnecessary that a log or piece of timber should be turned in either direction during the process of cutting, for the purpose of producing a piece of wood of the intended shape, then the chuck plates and roller support are to be left in a state of rest; and if the chuck plates and roller support are turned by machinery, as shown in the figures, then also the driving shaft y, and all the machinery connected therewith and before described, are to be left in a state of rest.

But when it is necessary that a log or piece of timber should be turned during the process of cutting, then that may be done by hand, as before mentioned; or if the machine be such as before described, then motion is to be given to the shaft y, and such motion regulated and (when necessary) accelerated or retarded by the machinery next to be described. And whenever motion is given by means of the driving shaft y to the transverse driving shaft K^1, and the movable chuck plate F, a similar motion will, by means of the train of wheels before described, be also communicated to the transverse driving shaft K^2, and the segment piece H, carrying the roller support G.

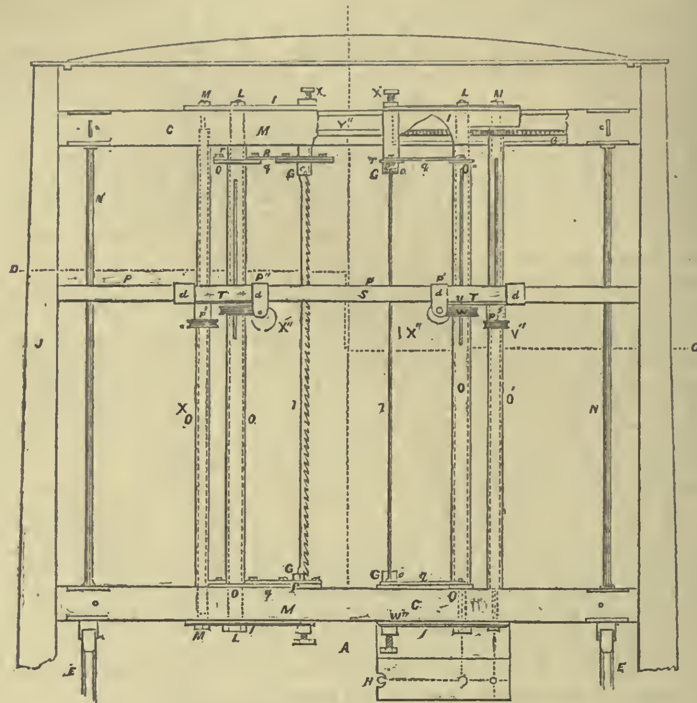
To show more clearly the mode in which the saws are mounted and worked, we have given in Fig. 1882½ a front elevation of the machine, with all the parts removed that have no relation to this branch of the invention, and also in Figs. 1883, 1884, 1885, 1886, 1887, and 1888, 1889, some of the more important of the minor details. Although any required number can be used at the same time, the sawgate is represented as fitted with two saw blades with their respective shackles and sliding frames; but as both saws are actuated by precisely similar means, we shall, for the sake of greater distinctness, confine ourselves to describing the parts belonging to one saw blade only.

The sawgate M M consists of two top and bottom rails C C, which are connected together by the upright rods N N, to the lower end of which are jointed the rods by which motion is communicated to the gate from the cranks of the main driving shaft. The saw blade l is attached at the top and bottom to two cylindrical axes G G, which are separately represented along with the parts peculiar thereto in Figs. 1883, 1884, 1885, 1886; Figs. 1883, 1884, 1885, being side elevations, and Fig. 1884 a cross section on the line E F of Fig. 1886. The axes G G are hollowed out in the centre from a to b, as represented in the cross section, Fig. 1884, and fit by means of the parts so hollowed out upon the projecting pieces H H, which form the extreme ends of the top plates of the shackles I I. The form of these projections H H is shown separately in Fig. 1887, which is a plan of the top plate of the shackles. When the axes G G are fitted upon H H, and the saw connected to them by the pins $c\,c$, the saw blade is brought to the proper degree of tension by means of the top screws $X^1\,X^1$. The points of these screws, which are conical and made of hardened steel, take into hollows formed in the pieces H H, so that the saw blade has thus, in so far as respects the screws by which it is stretched, perfect liberty to turn round in any direction, the friction of the bearing parts presenting a very trifling obstacle to its rotation. The saw is, however, limited at the same time in respect of angular motion by the sides of the recesses formed in the axes G G, and the neck which connects the bearing points H H of the shackles I I; the range allowed to the saw by the parts just described being still sufficiently extensive for all practical purposes. (It may be turned till it stands at an angle of 45 degrees, or even a greater angle, with the central line of the sliding carriage upon which the wood to be cut is placed.) It is to be observed, that when the saw is stretched, the points of resistance to its tension are not the rails of the sawgate; for the strain falls entirely upon the shackles or buckles I I, which, together with the rods L and M, form a frame complete in itself, which fits accurately into and slides upon the sawgate. By this improved method of mounting the saw, great facilities are obtained for connecting and disconnecting it from the frames, while the friction of the bearing points being reduced to a very small amount, the workman is enabled to direct the course of the saw in any intended line with great precision and ease.

On the rod or strut L there is closely fitted a hollow shaft or tube O^0, two ends of which bear against the top and bottom shackles I I. So that by this means it is prevented from moving in a longitudinal direction upon the rod L, but is still left free to be turned round upon it, as on an axis. To the upper and lower ends of the shaft or tube, there are securely fixed cross arms $O^2\,O^2$, corresponding with similar cross arms $P^2\,P^2$, which are keyed upon the axes G G of the saw. These two sets of cross arms are again connected with each other by rods $q\,q$, (a plan of which is given in Fig. 1888,) so that, if the hollow shaft O^0 be made to turn by any means either to the right or left, an equivalent movement of the saw upon its axes G G takes place at the same time. P P are two round rods, which are secured to the upright standards of the framework of the machine, and occupy positions parallel to each other, and also parallel with the sawgate. T is a bridge, or sliding bearing, which is free to slide to and fro upon the rods P P, that is, from one side of the sawgate to the other, being attached to the rods by the bosses $d\,d\,d\,d$. U and P^3 are two bosses inserted into the upper plate of the bridge T, in such a way that they are at liberty to revolve in the holes into which they are inserted; while they are prevented from getting out of their places by collars $f\,f$ formed on, or affixed to, their upper and lower ends. One of these bosses, U, embraces the upright hollow shaft O^0, and allows of its moving freely up and down within it. On the side of the hollow shaft O there is a feather e which takes into a corresponding groove formed in the boss U, so that if the boss is made to revolve, the hollow shaft must go round along with

it. W is a worm-wheel which is attached to, or formed in one piece with the brass U, and geers into an endless screw X, upon the end of which there is a hand-wheel X^2, so that the attendant may be enabled, through the intervention of the endless screw X, the worm-wheel W, the hollow shaft O, the cross-arms O^2 P^2, and the rods *q q*, to cause the teeth of the saw to be directed at pleasure, more or less towards the right or left, according to the form desired to be given to the piece of wood.

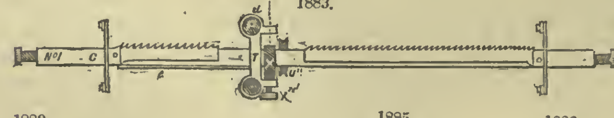
1882½.



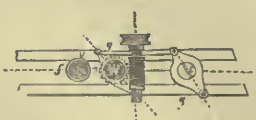
1887.

1888.

1883.



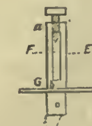
1889.



1884.

1885.

1886.



When the saw has been inclined towards either side of the sawgate (by means of the apparatus before described) during the operation of cutting a log or block of wood, the regular feeding in of the wood takes place by the advance of the travelling bed under the sawgate. The saw would, therefore, very soon be broken unless the shackles were made by a free lateral motion, or some other means, to advance towards that side of the sawgate to which the teeth of the saw are directed. To effect this object, the arrangement next to be described is adopted: V^2 is a hand-wheel fixed upon, or made in one piece, with the brass P^3, which is connected with a hollow shaft O* upon the rod M; being in this

respect exactly similar to the hollow shaft, O^0 and brass U, before described. The hollow shaft O* has pinions Y Y affixed to each end, which geer into racks Y^2 Y^2, which last are fixed to the upper and lower rails of the sawgate. In general the draft of the saw itself is sufficient to cause the shackles to move along the sawgate; but whenever any obstruction to the lateral movement is experienced, all that the attendant has to do is to turn the hand-wheel Y^2 in the required direction, which causes the pinions Y Y, by geering into the fixed racks, to draw the shackles and saw along with them.

The arrangements which have just been described for regulating the lateral and simultaneous movement of the shackles, both at top and bottom of the sawgate, serve the further purpose of keeping the saw at all times vertical in the sawgate, it being impossible, on account of the racks and pinions, for one of the shackles to be moved without a corresponding movement being produced in the other.

Not only may the machine be worked with either one or more saws at a time, but one saw may be used to cut in a curvilineal direction, while the other cuts in a straight line.

"Thus if both or either of the sides of a log should be intended to be cut in a curved or irregular line, that object may be attained by turning, from time to time, the saw in the required direction; and when simultaneously making two cuts in a log by my said machine, it is not at all necessary that the cuts should be made parallel with each other, for the lateral movements of the saw within the sawgate being perfectly independent of each other, each saw may be turned in the required direction for the purpose of making the intended cut in the line described, however much the two lines to be cut by the two saws may vary from each other.

"Neither is it necessary that two saws should be actually used for the purpose of cutting timber in one of my said machines, although two saws may be mounted in the sawgate; for the peculiar construction of my said sawing machine may be made available for the purpose of making single as well as double cuts. And if it should happen that the shape into which a piece of timber is intended to be cut requires the adoption of such a mode of proceeding, I can enter one of the saws and commence cutting a piece of timber with it, and after the cutting with one saw has proceeded the requisite distance, I can then enter the other saw also, so that both saws may then proceed with the cutting of the log; or the cutting with either or both of the saws alternately or simultaneously may be varied from time to time, as may be required for the purpose of cutting the pieces of timber into the desired shape."

This invention has recently been introduced into England from this country, and has been in active operation for two years in the government dock-yard at Woolwich, where the estimation in which it is held is fully testified by certificates of the highest officers of the admiralty, and other persons of distinction, in Europe, competent to judge of its merits. It has also been adopted by the government of Sweden; has met the approval of the officers of the Russian government and of several other continental naval boards. We are confident that the machines erected at Woolwich in 1847 were the first and only ones that ever had converted compass timber for a ship's frame for actual use. Mr. Cochran is now under contract for the construction, in England, of machines for the dock-yards of that country. Machines are now in the course of erection in this city, and are considered by the most competent judges to be one of the greatest improvements of the present day. "Cochran's Patent Machine for Sawing Ship Timber" is capable of cutting both straight and crooked work at the same time. One futtock can be sided at the same time the curvilinear and bevelled sides of another are being sawed, or a straight timber can be cut at the same time that a crooked one is sawed into planking, *with the grain of the wood.*

FUTTOCK PLATES. Flat iron bars or plates, receiving at one end the lower dead-eye of the top-mast rigging, and at the other the futtock shroud.

FUTTOCKS. In nautical language, the timbers between the floor timbers and the top timbers.

Gage. See Gauge.

GALVANISM. This term is generally used as synonymous with that of voltaic electricity, or the phenomena resulting from the evolution of electricity by the contact of different metals, or by chemical action, as manifested by the galvanic or voltaic battery. For descriptions of some of the more useful of these batteries and their practical application, see Electricity, Electro-Metallurgy, Telegraph.

GALVANIZED IRON. Iron covered with a coating of zinc and tin. This process is as follows. Clean the surface of the iron perfectly by the action of dilute acid and by rubbing; then plunge it first into a bath of zinc, stirring it about till it is alloyed superficially with this metal; then immerse it in a bath of tin, such as is used for making tin plate. The tin forms the exterior coat. Iron thus prepared is found to withstand the action of rust much longer than tin plate, and is now used extensively for gutters and leaders, and in other exposed situations.

GALVANOMETER. An instrument for ascertaining the presence of a current of electricity, especially galvanic or voltaic electricity, by the deviation which it occasions in the magnetic needle. The simplest form of galvanometer is a magnetic needle poised upon a point, and surrounded by one or more coils of copper wire covered with silk, the ends being either left free or terminating in two small copper cups containing mercury, for the convenience of communication with the source of electricity. When this needle is placed parallel to the coil, and in the magnetic meridian, it immediately deviates when the electric current passes through the coil; and the deviation is either to the east or the west, according to the direction of the current. See Electro-Magnetism.

GAS, *and the machinery employed in the manufacture of.* All substances, whether animal, vegetable, or mineral, consisting of carbon, hydrogen, and oxygen, when exposed to a red heat, produce various inflammable elastic fluids, capable of furnishing artificial light. We perceive the evolution of this elastic fluid during the combustion of coal in a common fire. Bituminous coal, when heated to a certain degree, swells and kindles, and frequently emits remarkably bright streams of flame, and after a certain period these appearances cease, and the coal glows with a red light.

The flame produced from coal, oil, wax, tallow, or other bodies which are composed of carbon and

hydrogen, proceeds from the production of carburetted hydrogen gas, evolved from the combustible body when in an ignited state.

If coal, instead of being burnt in the way now stated, is submitted to a temperature of ignition in close vessels, all its immediate constituent parts may be collected. The bituminous part is distilled over, in the form of coal-tar, &c., and a large quantity of an aqueous fluid is disengaged at the same time, mixed with a portion of essential oil and various ammoniacal salts. A large quantity of carburetted hydrogen, carbonic oxide, carbonic acid, and sulphuretted hydrogen, also make their appearance, together with small quantities of cyanogen, nitrogen, and free hydrogen, and the fixed base of the coal alone remains behind in the distillatory apparatus, in the form of a carbonaceous substance called *coke.* An analysis of the coal is thus effected by the process of destructive distillation: the products which the coal furnishes may be defined as follows:—

Oxygen, which was discovered by Priestley in 1774.

This gas has resisted all attempts to convert it into a liquid; it is colorless and inodorous, and heavier than atmospheric air, 100 cubic inches weighing 34·195 grains, while 100 cubic inches of the latter only weigh 31·0117. As atmospheric air is considered as unity when comparing the density of gases, the specific gravity of oxygen is 1·1026. It eminently supports combustion, all combustible bodies when introduced into it burning much more vividly than in common air; indeed it is to the presence of this gas that the property of supporting combustion, which common air possesses, is owing.

Hydrogen was discovered in the year 1766 by Cavendish. It is gaseous, and the lightest body known, its specific gravity being only 0·06896. This gas is colorless, and, when perfectly pure, inodorous. It is not perceptibly dissolved by water: it has a powerful affinity for oxygen, and is therefore eminently combustible. Intense heat is developed by the combustion of hydrogen in oxygen gas, but little light: the compound thus produced is water.

Carbon is well known under the form of coke, charcoal, lampblack, &c. It is one of the principal constituents of all varieties of coal, and is the basis of the illuminating gases.

It is a colorless and inodorous gas, rather lighter than common air, having a specific gravity of 0·9727; is sparingly absorbed by water, and does not precipitate lime-water. It is inflammable, burning with a beautiful blue flame; the product of its combustion is *carbonic acid.* Carbon unites with hydrogen in many proportions, and many of these compounds are produced during the distillation of coal, but the only two of importance are carburetted hydrogen and olefiant gas.

Carburetted Hydrogen is abundantly formed in nature in stagnant pools, ditches, &c., wherever vegetables are undergoing the process of putrefaction: it also forms the greater part of the gas obtained from coal. Carburetted hydrogen consists of 100 volumes of vapor of carbon and 200 of hydrogen. It is colorless, and almost inodorous; is not dissolved to any extent by water; and is much lighter than atmospheric air, its density being 0·5594. It is very inflammable, burning with a strong yellow flame: the products of its combustion are carbonic acid and water. The carburetted hydrogen, or coal-gas, when freed from the obnoxious foreign gases, may be propelled in streams out of small apertures, which, when lighted, form jets of flame, which are called *gas-lights.*

Olefiant Gas is thus named from having the property of uniting and forming an oily substance with chlorine. It is a product of the distillation of oil, resin, and also of coal, when the process is well conducted. It is colorless, tasteless, and without smell when pure. Water dissolves about one-eighth of its bulk of this gas. It is formed of two volumes of hydrogen, and two of the vapor of carbon, condensed into one volume. It burns with an intense white light, and requires a large portion of oxygen for its combustion; one volume of the gas requiring not less than three volumes of pure oxygen, or fifteen volumes of atmospheric air, for decomposition. The products of the combustion are water and carbonic acid.

Sulphur exists in coal as an impurity, under the form of the sulphuret of iron. During the distillation it is decomposed, the sulphur combining with a portion of hydrogen, and escaping under the form of sulphuretted hydrogen gas, part of which unites with the ammonia, and is condensed in the aqueous fluid which floats on the surface of the tar; while another portion escapes uncombined, and would mix with and deteriorate the gas, were it not intercepted by the lime purifiers.

Sulphuretted Hydrogen is a colorless gas, with an offensive taste and odor, resembling that of putrefied eggs. It dissolves in its own bulk of water, to which it communicates its taste, odor, and characteristic properties. It is combustible, burning with a blue flame, and emitting a suffocating smell similar to that of a burning match. During the combustion its hydrogen unites with oxygen to form water, while its sulphur unites with another portion of oxygen to form sulphurous acid. It is to the presence of the vapor of this substance that the disagreeable property of tarnishing metals which characterizes the combustion of impure gas is owing. Its specific gravity is generally estimated at 1·178.

Nitrogen is one of the constituents of coal. It has the property of extinguishing burning bodies, and is not absorbed by water; its specific gravity is 0·9760, being lighter than common air, of which it forms a constituent part.

Ammonia is formed during the distillation of coal, and of all organic substances containing nitrogen. In such distillation the nitrogen unites with hydrogen in the proportion of one to three, and ammonia is the result. It is a colorless gas, very pungent, acting strongly on the eyes and nose when respired. It dissolves in a very small portion of water, one volume taking up about 750 of the gas, forming a liquid possessed of similar properties, and sold in the shops under the name of Spirits of Hartshorn.

The presence of *Cyanogen* is frequently detected in coal-gas before purification; it contains its own bulk of nitrogen, and twice its volume of the vapor of carbon.

Chlorine is one of the elementary substances, supporters of combustion. It is possessed of striking properties, but that which alone is of interest at present is its action on olefiant gas. On mixing chlorine with a gas in which olefiant is contained, a diminution of volume is observed, and drops of oil are seen to fall on the surface of the water over which the operation is conducted. This fact enables us to estimate correctly the bulk of olefiant in any given portion of mixed gases.

With a view to the generation of gas on a large scale, the coal is put into vessels called retorts, and furnished with pipes connected with reservoirs, to receive the distillatory products. The retorts are fixed into a furnace, and heated to redness: the heat develops the gaseous and liquid products of the coal: the latter are deposited in receivers or tanks, and the former conducted through lime-water, or thin strata of the hydrate of lime, and purified. The sulphuretted hydrogen and carbonic acid, which are mixed with these, become absorbed by the lime and moisture, and the pure carburetted hydrogen is stored up in a vessel called a gasometer, and is then ready for use. From the reservoir in which the gas has been collected proceed pipes, which branch out into small ramifications, until they terminate at the place where the lights are wanted; and the extremities of the branch pipes are furnished with stop cocks, to regulate the flow of the gas into the burners or lamps.

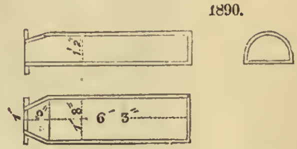
The production of gas-lights is therefore analogous to that of flame produced from tallow, wax, or oil. All these substances possess, in common with coal, the elements of certain matters, which are capable of being converted into inflammable elastic fluids by the application of heat.

The capillary tubes, formed by the wick of a candle or lamp, serve the office of the retorts, placed in the heated furnace in the gas-light process, and in which the inflammable gaseous fluid is developed. The wax, tallow, or oil, is drawn up into these ignited tubes, and is decomposed into carburetted hydrogen gas, and from the combustion of this substance the illumination proceeds. In the lamp, as well as in the candle, the oil or tallow must therefore be decomposed before they can produce a light; but for this purpose the decomposition of a minute quantity of the materials successively is sufficient to give a good light: thus originates the flame of a candle or lamp.

Nothing more therefore is required in the gas-light process which coal affords, when submitted to a temperature of ignition in a close vessel, than to collect these products in separate reservoirs, and to convey one of the products, the inflammable gas, by means of pipes and branching tubes, to any required distance, in order to exhibit it there at the orifice of the conducting tube, so that it may be used as a candle or lamp.

The whole difference between the greater process of the gas-light operation and the miniature operation of a candle or lamp, consists in having the distillatory apparatus at the gas-light manufactory at a distance, instead of being in the wick of the candle or lamp—in having the crude inflammable matter decomposed, previous to the elastic fluid being wanted, and stored up for use, instead of being prepared and consumed as fast as it proceeds from the decomposed oil, wax, or tallow; and lastly, in transmitting the gas to any required distance, and igniting it at the burner or lamp of the conducting tube, instead of burning it at the apex of the wick.

1890.



Retorts.—The proper mode of constructing retorts in which coal is distilled, and the art of applying them, form objects of primary importance in every gas-light establishment.

The forms of the retorts used at the present time are various. The annexed Figs. 1890, represent sections of a retort, of cast-iron, commonly known by the name of a D. The charge is 3 bushels, or 2¼ cwt., which may be drawn at the end of six hours. The dimensions cannot be increased with economy beyond those marked on the drawings. Retorts of smaller dimensions are more usually adopted.

Mode of setting a bench of five D retorts.—These Figs. represent a front elevation, two sections and plan of a "bench" of five common retorts, such as are in general use.

Fig. 1892 is a front elevation. Fig. 1893, a transverse section, through *a b* in Fig. 1894. Fig. 1894, a longitudinal section, through *c d* in Fig. 1893.

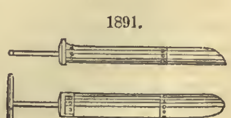
Fig. 1895 is a plan showing the furnace and side openings below the fire-tiles, on which the lower retorts rest, and the bedding of the lower retorts. Fig. 1896 is a plan over the three lower retorts, the two upper retorts being removed. Fig. 1897 is a plan over the oven-arch, showing the flues, &c.

The same letters refer to corresponding parts in the several views.

A. Retorts of the kind called D's. Some engineers prefer those of a cylindrical form, but D's allow of the coal being laid in thinner strata, consequently it is more evenly acted upon by the heat, an advantage under every circumstance. Set in the manner shown in the Figs. the bottoms of those retorts placed immediately over the furnace are well protected. The dimensions are—length 7 feet, diameter 1 foot 2 inches, thickness of metal 1¼ inch. Their weight is about 15 cwt. of cast-iron.

The most economical charge is two bushels, or 1½ cwt. of coal to each retort, drawn at the end of six hours. This charge will fill the retort to the depth of about five inches; if the coal be moderately small, the layer will be rather less in thickness. At a heat of 27° of Wedgewood's pyrometer, or that of melting copper, each charge ought to produce about 650 cubic feet of gas, of the specific gravity ·400, (the specific gravity varies between ·390 and ·420, according to the heat at which the retorts are worked, and the quality of the coal carbonized,) from Newcastle coal, making the products of the entire bench equal to 3250 cubic feet in six hours.

1891.



To introduce the coal into the retorts, a "scoop" ought to be employed, in preference to the primitive mode, with a shovel. The scoop is a semi-cylinder made of thin plate-iron, six feet six inches long, and twelve inches in diameter, with a cross-handle at one end, represented in Fig. 1891.

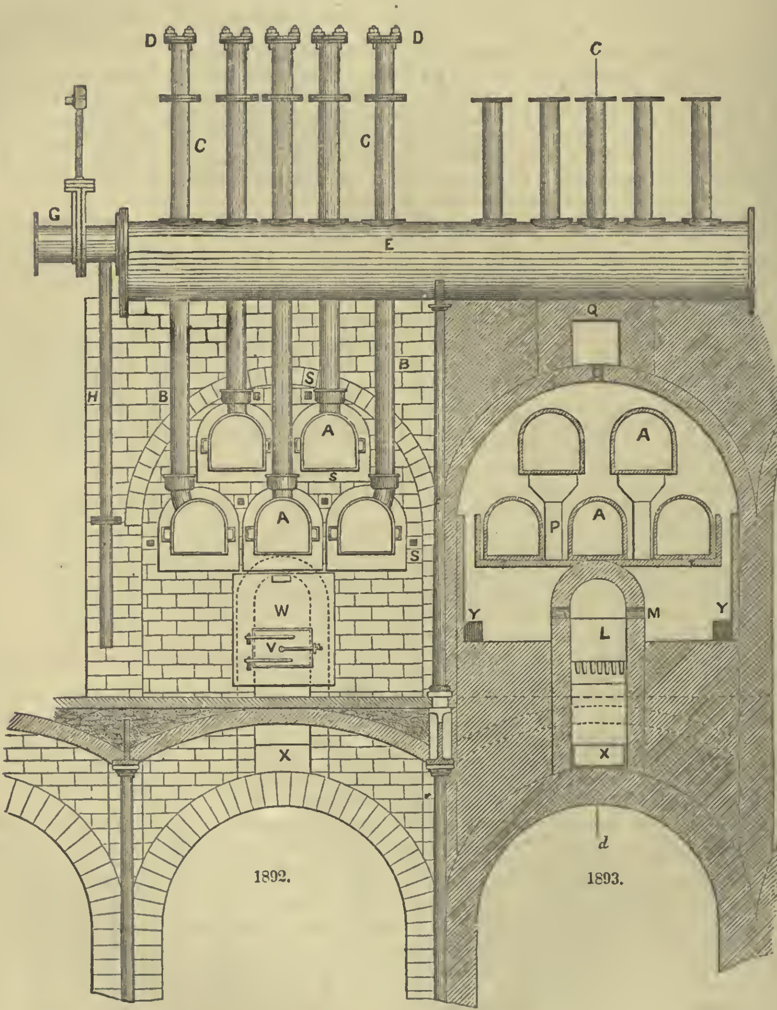
The charge for the retort is placed in this; one man takes the cross-handle, and two others at the opposite end lift it with its contents up to the retort; it is then pushed forward, quite to the bottom, turned round, and withdrawn immediately, and the coal left in the retort raked into an even stratum.

The lid, previously luted, is now quickly jointed on to the retort-mouth. It must be obvious that the loss of gas by this simple method is very trifling, the whole operation not occupying more than forty seconds; whereas, when the shovel is used, the coal is thrown in so much by degrees, that more gas is

lost, owing to the greater length of the operation, and the heat producing some effect on each separate shovelfull: in either case the loss is inconsiderable.

Previous to drawing the charge, loosen the lids of the retorts, and apply a light to the issuing gas, beginning at the upper retorts. This precaution is necessary to prevent explosion.

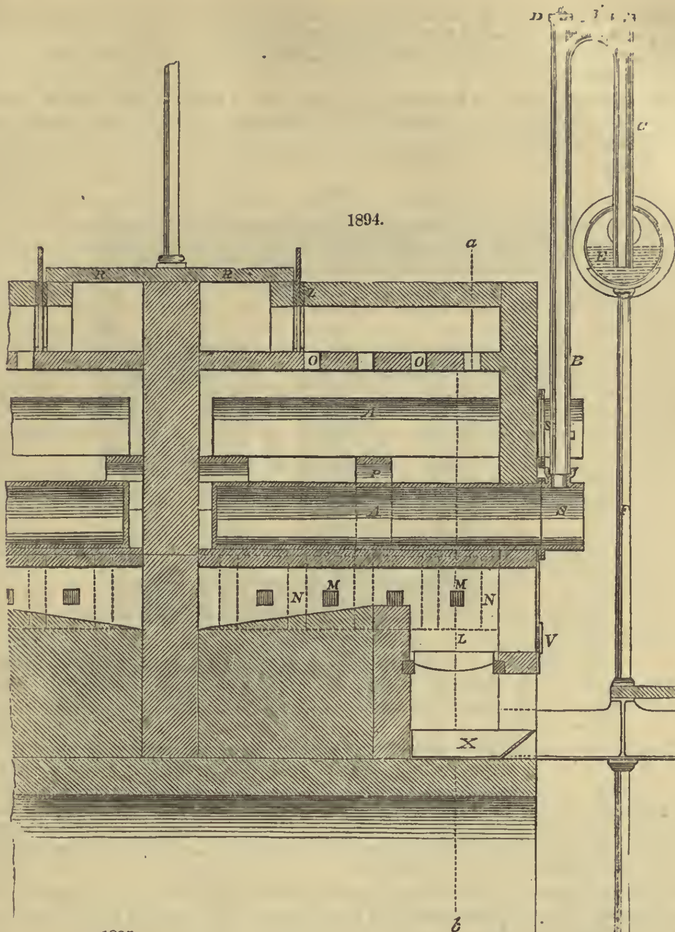
S is the mouth-piece, ten inches long, with a socket cast on the top to receive the stand-pipe. There ought to be a neck to this socket, as shown in Figs. 1892 to 1894; because the joint, when close upon the top, from its greater thickness, retains much heat, and decomposes the tar which will accumulate at this place and eventually choke the pipe with hard carbon. The length of the neck may be from four to five inches.



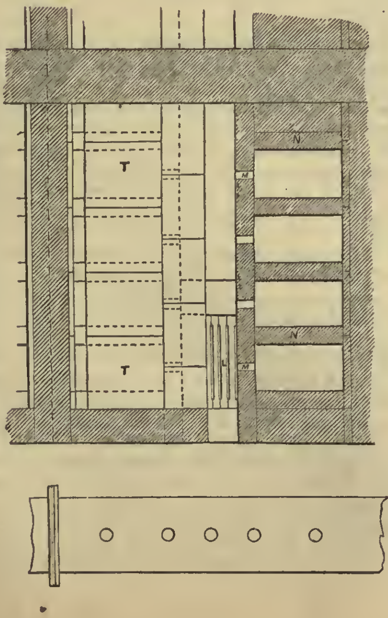
1892. 1893.

The mouth-piece is three-quarters of an inch in thickness, secured to the retort by bolts, and a cement joint made between their flanches. Iron cement is the most valuable for this purpose, and is used in all places where heat is present. It may be compounded as follows: To one ounce of sal-ammoniac, add one ounce of flowers of sulphur, and thirty-two ounces of clean cast-iron borings; mix all well together, and keep the composition dry. When the cement is wanted for use, wet the mixture with water, and when brought to a convenient consistence, let it stand for a few hours; then apply it to the joints, and screw them together. The flanches ought to be kept about three-eighths of an inch apart, by wrought-iron wedges, and the cement well filled in between them with a square blunt-pointed chisel, called a caulking-chisel; the cement is stopped from being driven through by a hoop of thin iron placed inside the pipe or retort to be thus operated upon, which is afterwards removed. A considerable degree of action and reaction takes place among the ingredients, and between them and the iron surfaces, which causes the whole to unite as one mass; the surfaces of the flanches become joined by

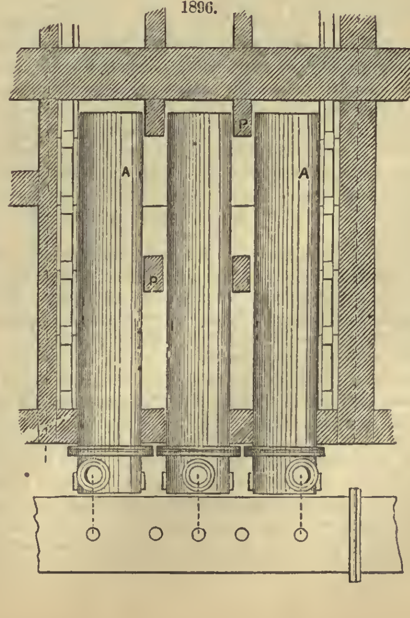
1894.



1895.



1896.

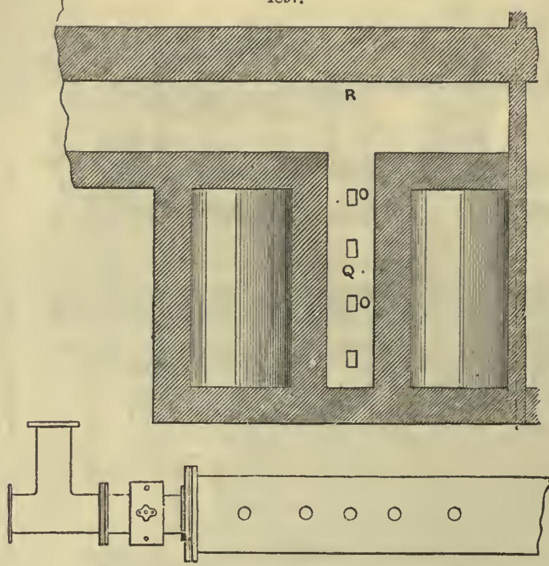


a species of pyrites, all the parts of which adhere strongly together. Mr. Watt found that the cement is improved by adding some fine sand from the grindstone trough.

A very economical joint for the retort mouth-piece is made of five parts of fine clay, and one part of the mixture just described.

The face of the retort mouth-piece is bevelled inwards, and is chipped and filed, if necessary, to remove any lump that would prevent the lid from fitting close; a clean and true casting, however, seldom requires this to be done.

1897.



The lid is jointed on to the face of the mouth-piece, with "luting" made of the spent lime from the dry purifiers, mixed with a little fire-clay, and tightened into its place by a strong, square-threaded screw, and cross-bar of wrought-iron, the ends of the cross-bar being passed through projecting ears, against which it bears when the screw is turned.

B is the "stand-pipe," through which the gas, as it is generated, passes from the retort; it is three or four inches in diameter at the top, increasing to five inches at the bottom, to prevent the tar which adheres to the lower parts from obstructing the flow of the gas. The lowest joint is made with a socket, instead of a flanch, to allow for some expansion without injury.

B′ is the "bridge-piece," connecting the stand and dip-pipes.

C is the "dip-pipe," passing through the upper metal of the hydraulic main, upon which it is jointed, and having its lower extremity, which is three inches in diameter, immersed four or five inches into the tar contained therein. The holes in the hydraulic main, through which the dip-pipes pass, are generally drilled and chipped out while the apparatus is in process of erection; because they are at unequal distances from one another. The height of the dip-pipes from the surface of the tar, measured from the lower bend of the bridge-piece, ought to be sufficient to contain the perpendicular head of tar forced up into them by the pressure of the gas from the *working* retorts. This would probably in no case exceed three feet.

D D are the bonnets, to be removed when the pipes require clearing, jointed by putty and pasteboard.

E is the "hydraulic main," running the entire length of the retort-house, over the benches, in a perfectly horizontal direction, and sufficiently high up to allow of head-room, and to be removed from the flame issuing from the retorts while charging. They are sometimes turned the reverse way to that shown in the Figs., and made to rest upon the brickwork of the benches; but this is inconvenient when the brickwork has to be taken down or repaired.

This main is three-quarters of an inch in thickness, and cast in convenient lengths, contrived to reach over two benches; in this case they would be equal to 13 feet 6 inches. The joints are made with iron cement. Its use is to cut off the communication between the retorts, when one or more benches are charging or open. Being half full of tar, the gas evolved from the retorts in action remains in the upper part, and the ends of the dip-pipes immersed under the surface are effectually sealed.

The diameter of the hydraulic main must be sufficient to form a reservoir capable of supplying the quantity of tar contained in the open dip-pipes without suffering it to fall below their immersed ends, and thus open a communication between the open and working retorts.

In the general arrangement of the hydraulic main two things must be observed. First the diameter must be sufficient to supply at least 20 inches perpendicular head of tar to each dip-pipe, without causing the general level to fall below their immersed ends: and secondly, the lower part of the cir

cumference of the pipe, which conveys the gas to the condensers, must be so placed that the tar may always be kept from rising too high, and either choking the free exit of the gas or increasing the working pressure of the retorts unnecessarily. The diameter of the main in the engraving is 18 inches—amply sufficient for fifteen benches of retorts.

F is a light, hollow, cast-iron pillar, supporting the hydraulic main in the centre of each length; it is based upon the cast-iron girder which supports the firing-floor.

G is the pipe through which the gas makes its exit from the hydraulic main to the condensers, furnished with a slide-valve to disconnect the mains at each side of the house, when at any time it may be found requisite to repair or clear them.

H is a small pipe for conveying the surplus tar formed in the hydraulic main to the tar-well situated beneath the firing-floor; its lowest extremity is sealed, by being immersed in the tar contained in the well, or in a small vessel by the side and connected with it; the latter is the most convenient. This surplus pipe is not absolutely necessary, because the siphon at the bottom bend of the first stand-pipe would perform its duty, but it is advisable to draw off the tar as soon as possible.

In the construction of retort-houses the firing-floor is raised upon flat 9-inch brick arches over the coke vault, high enough to give head-room, a space about 24 inches wide being left in front of the benches for the coke to fall through when drawn from the retorts: it should be of such a material as will not be injured by frequent blows; some prefer cast-iron. The flat arches supporting the floor spring from cast-iron girders fixed at one end in the brickwork of the benches, at the other in the wall of the retort-house. The distance between the centre and centre of these girders is six feet nine inches.

L is the furnace for heating the retorts; its breadth is 14 inches, the length of the fire-bars 24 inches. The bars are placed loosely upon the bearers, and must occasionally be "clinkered," or lifted from their seat in the front and cleared from the slag which adheres to them.

M M are side openings, three inches square, left in the brickwork, through which the heat of the furnace passes.

N N are 4½-inch walls, built of fire-bricks, one between each of the openings M; they serve to support the fire-tiles T, on which the outside lower retorts rest. The direction of the flues is shown by arrows.

P P are fire-bricks, placed on end, and a fire-lump, upon which the two upper retorts rest. The heat acting on these being somewhat moderated, no guards of fire-tiles are necessary.

O O are openings, 3 inches by 4½, in the crown of the main arch communicating with the branch flue.

Q is the branch flue, one being built over the centre of each bench of retorts.

R is the main flue, running the entire length of the benches, and connected with the chimney into which all the branches lead. Between this main flue and each branch is a damper Z, to regulate the draught through the furnaces.

S′ S′ are cast-iron plugs, covering sight-holes, through which the heat of the retorts is seen and judged of.

V is the furnace-door, protected by a fire-lump inside.

W is a cast-iron plate, 1½ inch thick, on which the fire-door is hinged, serving also to protect the face of the brickwork which it covers. In the centre, and about six inches above the fire-door, a square opening is cast for the admission of an iron spout, when it is required to burn tar.

X is a pan at the bottom of the ash-pit, for evaporating ammoniacal liquor, and the offensive unsaleable liquid products which cannot be disposed of otherwise.

Y Y are openings left in the walls N, by which the carbon deposited from the furnace is cleared away.

It must be obvious that the durability of the distillatory apparatus greatly depends on the manner in which the heat is applied to effect the decomposition of the coal contained within the retort. If the heat be very intense, the whole vessels are rapidly destroyed; if it be too languid, the distillation is protracted, the gas is of inferior quality, much fuel, time, and labor are wasted to no purpose, and the retorts are speedily deteriorated, as the heat acts upon one part more than upon another. The experiments by which the present plan of heating retorts was arrived at, were many and expensive. Originally they were built in brickwork singly, and heated by flues passing beneath and over them, without any guard, except in some instances that of an iron saddle. They were afterwards placed in pairs, then in a great number; but nevertheless, until the guard of fire-tile was used, the wear and tear was enormous.

The great obstacle to working more than two retorts to one furnace evidently arose from the difficulty of conducting the heat by means of flues around the series of retorts in such a manner that it should act with equal force on all. Different workmen constructed these flues in different ways: in short, the forms varied in every possible manner, and still with the same result. The fuel required for heating the retorts, when set without guards, was less by nearly ten per cent. than that required for the same purpose on the oven plan; but the greater duration of the retorts much more than compensated for the additional fuel.

The oven represented in Figs. 1893 and 1894 is one of the latest arrangements. The heat from the furnace passes through the square openings M at each side, and is thus equally divided along the whole length of the retorts; from between the walls N it rises between the fire-tiles at the outer sides of the lower retorts. The flame is not suffered to impinge upon any part, but is equally distributed throughout the oven, and consequently the retorts work and "burn out" evenly. The lower retorts, which would otherwise be exposed to a more direct heat, are carefully guarded by fire-tiles, which at the same time prevent the bottoms from bulging. The openings O at the top of the main arch act more in the manner of safety-valves than flues, serving to regulate the final exit of the heated air, and, being distributed along the outer length, they do not draw the flame to one part.

The whole interior of the oven, as well as those parts in contact with the flame, must be constructed of fire-bricks. The main arch, six feet in span and half a brick in thickness, is formed of bricks moulded on purpose to suit the curve, the joint being kept as close as possible. As this arch is permanent, much care should be taken in its formation.

A bench of retorts on this plan, if well and regularly used, ought to last from 12 to 14 or even 15 months, and ought never to be suffered to become cold. The first portion of oxide which forms upon the surface, when allowed to cool, cracks and falls off, leaving a new surface to be acted upon the next time it is heated.

When it becomes necessary to reduce the number of working retorts on the approach of summer, those that are nearly burned out should be selected; or, if there are none in this condition, "let them down" very gradually, by keeping the damper closed after the fire is raked out: it will be a week before they become quite cold. The same precaution should be taken in "getting up" the heat—opening the damper gradually.

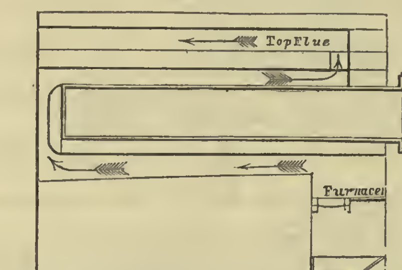
When a bench of retorts is newly set, the green work must be suffered to get quite dry before any fire is lighted.

The results of a chaldron, or 36 bushels of Newcastle coal, weighing 27 cwt., distilled in retorts set in the manner just described, and the quantity of fuel used for the distillation, will be as follows:—

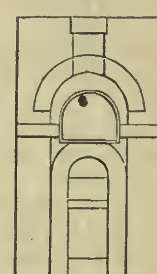
Gas of specific gravity ·400...	8650	cubic feet.	Gas of specific gravity ·400.	8600	cubic feet.
Coke of good quality..........	14	cwt.	Coke..............................	13	cwt. 3 qr. 14 lb.
Ammoniacal liquor..............	12½	gallons.	Ammoniacal liquor............	12½	gallons.
Thick tar..........................	12	do.	Thick tar	11¾	do.
Tar used as fuel................	19	do.	Coke used as fuel............	6	cwt.
Lime for purifying.............	86	lbs.	Lime for purifying...........	84	lbs.

In country towns, where the quantity of gas made during the winter seasons does not exceed 10,000 cubic feet in twenty-four hours, the retorts must be set singly, as represented in Fig. 1898, the flue passing beneath and over the retort, which rests upon a half-brick arch, cut flat at the top to receive it; the end is guarded by a thick fire-tile.

1898.

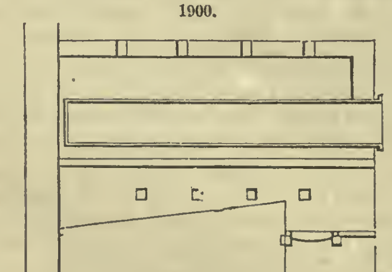


1899.

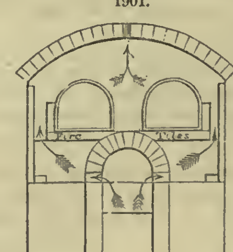


When the quantity of gas made in twenty-four hours does not exceed 30,000 cubic feet, or when the quantity made is decreased 1200 cubic feet at a time, on the approach of summer, the ovens may contain two retorts, as shown in Fig. 1900. The flues are arranged in a similar manner to those in a large oven.

1900.



1901.



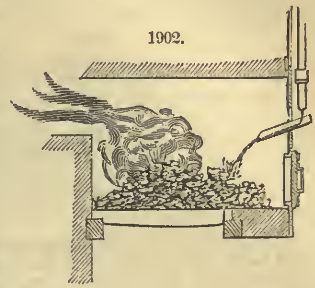
The *Fuel* used for heating the retorts may be either coal or coke, according to the relative value of each in the district. If coal is used, a well-regulated bench will require about 18 to 20 per cent. of the coal distilled; that is to say, to heat the retorts for the production of 12,000 cubic feet of gas, from 5 to 5½ cwt. of coal will be necessary. The use of coke as fuel is general in those places where coal is valuable, and where coke is less in requisition as fuel for manufacturers. The quantity of coke for heating the retorts will vary from 40 to 45 per cent. of the quantity produced; that is to say, from 16 to 18 bushels of coke are requisite to distil one chaldron of coal, or 5 cwt. will distil one ton.

Mr. Croll has introduced a system of using the coke as fuel while red-hot. The charge from the retorts is drawn into a wrought-iron carriage, and immediately taken to those furnaces which require feeding. The saving effected by this simple process is equal to 10 or 12 per cent. The reason is evident; because when a quantity of black coke is thrown on the previously-heated mass of fuel, the flues will to a certain extent become cool, since the heated air is absorbed. When hot coke is thrown in, no absorption takes place, and the flues are kept up at a uniform temperature

The use of tar as fuel has of late become frequent, and is the most economical, as far as it is available. In almost every instance it is worth more to burn than to sell. The quantity required for carbonizing a chaldron of coal varies from 24 to 27 gallons.

The furnace used for burning tar is the same as that used for other fuel, and is fed by a small continuous stream, conducted by a wrought-iron service-pipe, from a tank placed on the top of the retort-benches, on to a sheet-iron spout projecting a few inches outside the furnace-plate, and into the furnace itself, as shown in Fig. 1902, were it spreads over a "breeze-bottom," previously brought to a red heat.

1902.

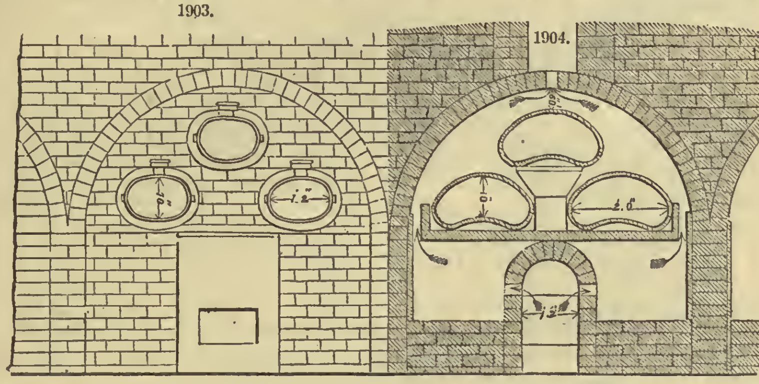


When retorts have been at work for some months, their interior surfaces become incrusted with a hard carbonaceous deposit, approaching, in some of its properties, to plumbago; in process of time carburet of iron and the more infusible parts of the coke form a thicker crust, which it becomes necessary to remove, both to prevent the destruction of the retort, and to allow the fuel to have full effect upon the coal contained within. This was formerly effected with great difficulty by crowbars, the force required often increasing the evil it was intended to remedy.

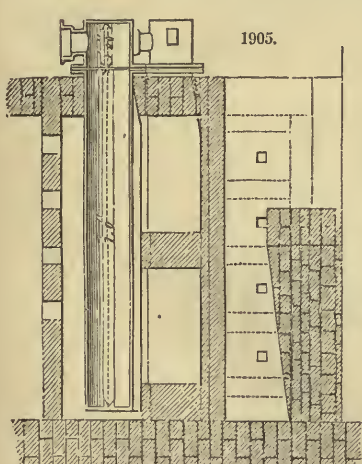
It was afterwards found, that leaving the retort open, and allowing cold air to come in contact with the heated interior, the deposit contracted, and could be broken away in about twelve hours without danger to the retort.

In order to take off this crust without endangering the retorts, an air-blast is used, as follows:—A cast-iron pipe, about three inches in diameter, is carried along the front of the benches, at a little distance above the upper retorts; at points in this pipe, directly over every retort, a screw and plug is attached, into which screw, when the plug is removed, a wrought-iron service, about an inch in

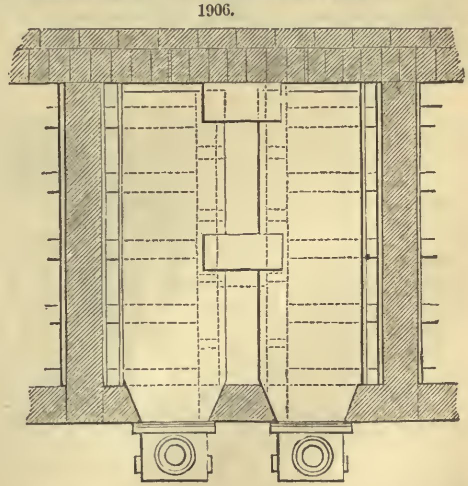
1903. 1904.



1905.



1906.



diameter, can be fixed, and led into any open retort The main pipe is connected with a blowing cylinder, worked by the steam-engine, so that a strong blast can be made to impinge upon any part of the hard incrustation, which gradually yields to it, and may then be removed without difficulty.

Ear-shaped retort.—Fig. 1903 is a front elevation of a bench containing three retorts

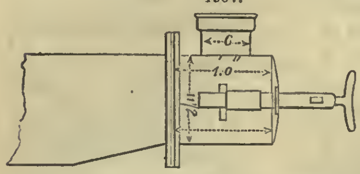
Fig. 1904 is a section taken transversely.

Fig. 1905 is a longitudinal section through the centre of the arch.

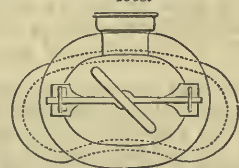
Fig. 1906 is a plan of Fig. 1904.

Figs. 1907, 1908, and 1909 are views of a mouth-piece on a scale of ½ an inch to a foot, which will show the method usually adopted for securing the lid in all ordinary retorts.

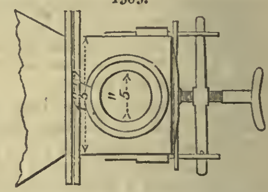
1907.



1908.



1909.

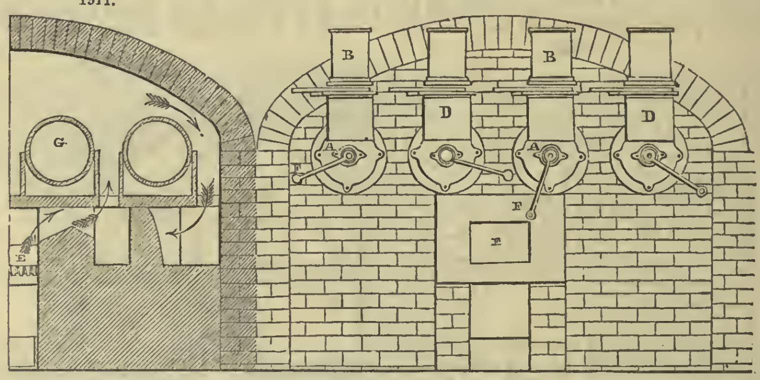


The great objection to the ear-shaped retort is, that the bottom bends are liable to become filled up with hard carbon, and when that is the case they are sure to crack. The principle on which they are constructed is good; and if they could be charged properly, viz. with a stratum of coal from 3 to 3½ inches thick, evenly spread over the bottom, they would be found to make more and better gas than D's and circular retorts, (where the stratum of coal is thicker,) simply because it would be more evenly acted upon. In all cases, with the same degree of heat, the thinner the stratum of coal the better the gas.

The mode of setting these retorts may be precisely similar to that explained in Figs. 1902 and 1903.

Brunton's patent.—Fig. 1910 represents a front view of a bench of four retorts, upon Mr. Brunton's principle.

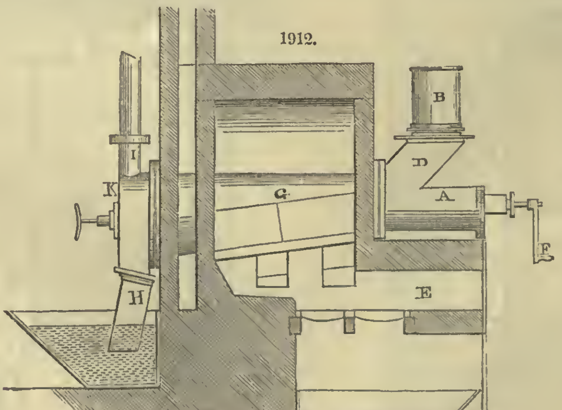
1911. 1910.



A A are the retort-mouths, the lids of which are fitted with stuffing-boxes, for the reason to be presently described, and permanently jointed in their places with iron cement.

B B are hoppers, capable of holding from 20 to 28 pounds of coal, which, when an air-tight slide valve C is drawn back, falls into the retort through the neck D: the valve is closed immediately.

1912.



E is the furnace, projecting beyond the face of the brickwork in which the retorts are set.

F F are handles for working a piston contained in the mouth-piece A.

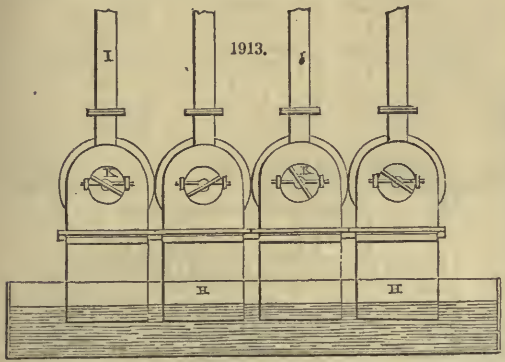
Fig. 1911 is a transverse section of one half of a bench. The retorts G, shown as circular, may be varied in form if thought necessary. We believe the patentee gives thepreference to those of a D shape

E is the furnace; the direction of the flues is shown by arrows.

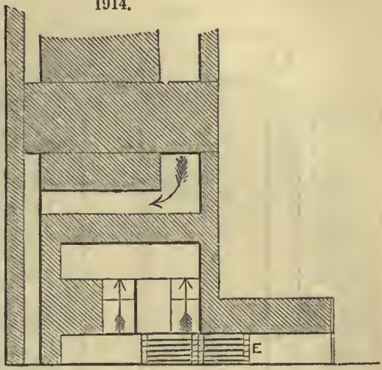
Fig. 1912 is a longitudinal section through the centre of the furnace.

H is a short pipe, open to the interior of the retort, sealed at the lower end by dipping into water, through which, after a charge is thrown into the retort from the hopper B, a portion of coke is expelled, by advancing the piston contained in the mouth-piece.

1913.



1914.



I is the pipe by which the gas, as it is formed, passes to the hydraulic main.

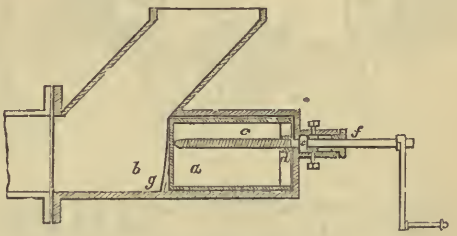
K is a bonnet, to be taken off at any time when required to examine the interior of the retort.

Fig. 1913 is a back view of Fig. 1910.

Fig. 1914 is a plan below the retorts. (The same letters refer to corresponding parts in all the figures.)

The annexed diagram, Fig. 1915, will explain the construction of the piston before alluded to.

1915.



a is the piston, drawn back in the proper position to receive a charge, which, when the slide-valve is opened, will fall into the space *b*, and be propelled forwards into the heated part of the retort by turning the screw *c*, which works in a nut *d* on the back of the piston.

e is a collar upon the shaft of the screw, working between the bottom of the stuffing-box and a washer held in its place by four pins. The stuffing-box is made tight in the usual way, by screwing the gland *f* against a gasket.

g is a shield loosely attached to the front of the piston, to prevent the accumulation of small coal-dust in the mouth of the retort. When the charge is thrust forward, the piston is turned back directly into the mouth, to preserve it from the action of the heat.

That part of the retort adjacent to the flues only is heated, consequently the only part liable to much wear and tear.

The only part requiring renewal is that of the retort situated between the outer walls of the bench, and weighing about 9 or 10 cwt. The fuel required to carbonize the coal is about 25 per cent. in coal on the quantity distilled.

Reciprocating retort, the invention of Mr. George Lowe.

It has been stated that the first portion of vapor produced by coal when undergoing destructive distillation in ordinary retorts will, when converted into gas, form that of the most brilliant quality, and it is to effect this that the following arrangements have been patented.

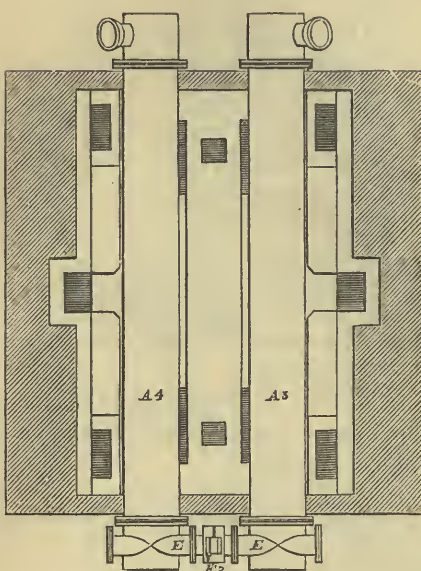
Fig. 1916 is a back elevation of two pairs of retorts. A^1, A^2, A^3, A^4 are the retorts; B B the stand-pipes; C C C, slide-valves for opening and shutting off the communication between the retorts and hydraulic main; D is the hydraulic main. The front elevation differs but little from it.

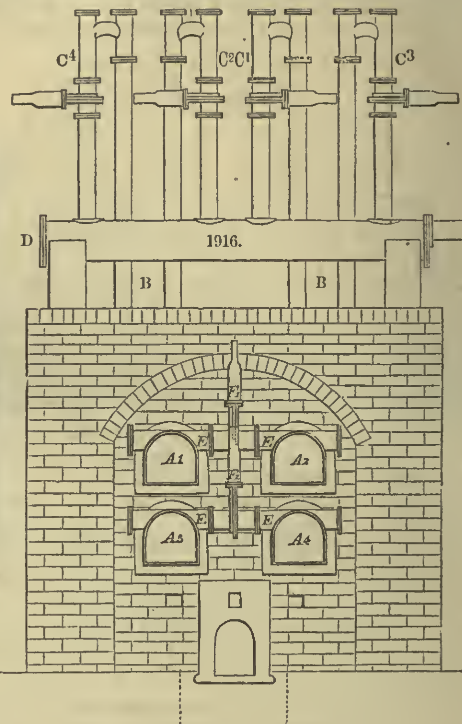
Fig. 1917 is a plan of the lower pair of retorts; the operation is as follows:—Supposing the entire bench to be at the requisite heat for decomposing the coal, and that they are working six-hours' charges, the lids of the retorts A^1 and A^3 are removed, and by means of scoops (each half the length of the retort) the coal is introduced at both ends, and the lids immediately secured in their places: the slides F^1 and F^2 are opened, and C^1 and C^3 closed. The bituminous vapors that rise first will pass through the pipes E E, and thence through the entire length of the hot retorts A^2 and A^4, and be converted into gas, which will pass to the hydraulic main by the stand-pipes on which the slide-valves C^2 and C^4 are fixed, and which remain open. When the distillation has gone on for half the duration of the charge—viz. three hours—the valves C^1 and C^3 are opened, F^1 F^2 shut, and the gas evolved from the retorts A^1 and A^3 passes through the stand-pipes attached to them. The retorts A^2 and A^4 are now charged, the mouths closed, the valves F^1 and F^2 again opened, and C^2 and C^4 shut. The operation is now reversed, the first vapors passing through the two first-charged retorts until their charge is expended, when C^2 and C^4 are opened, F^1 and F^2 closed, and the charge drawn. They are then immediately recharged, and the operation of opening and closing the valves repeated.

Retorts on this construction have been worked, and are found to act well, producing gas of average quality and in greater abundance than by the ordinary method. The reason of the gas being only of

an average quality is, that the carburetted hydrogen made after the production of bituminous vapor has ceased, still passes over the red-hot surface of another retort and deposits some portion of its carbon, the rich gas formed by the conversion of the bituminous vapor only serving to make up the deficiency.

1917.





If, instead of having only two retorts in a set, the number could be increased to six, and after the first hour the gas be allowed to pass away on the ordinary plan, both the quantity would be augmented and the quality improved.

Revolving web retort.—This retort is arranged so that the coal is acted upon in a thin stratum and converted into gas at once: the chemical advantages of this method are many;—all the elements of the coal are liberated at nearly the same time, and unite with one another in such proportions as to form gas of the best illuminating quality, and in greater abundance than when the coal is carbonized in mass. The condensed bituminous vapor which forms tar in the ordinary process is by this nearly all converted into olefiant gas.

1918.

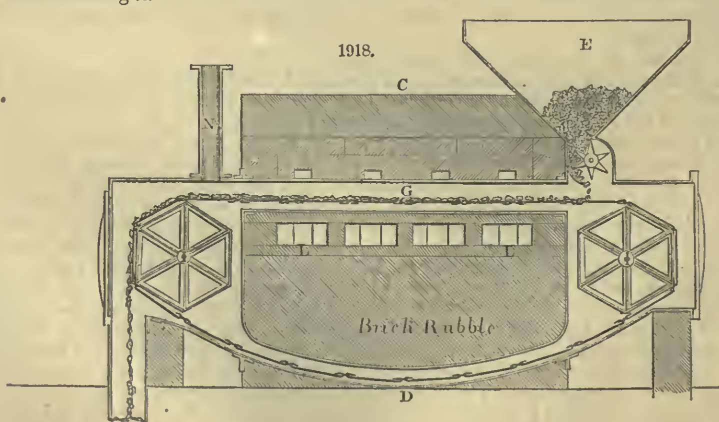
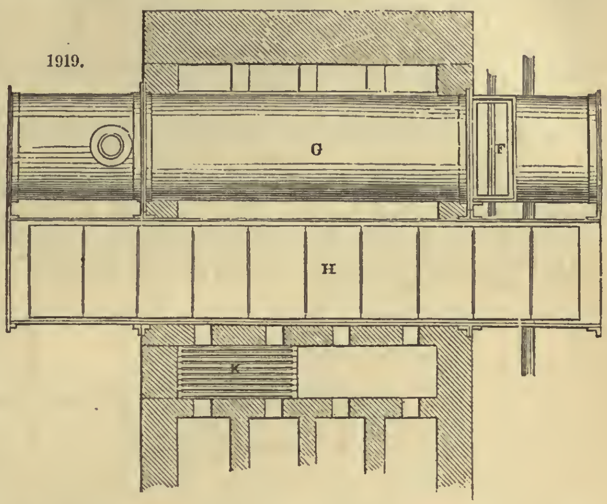


Fig. 1918 is a longitudinal section through A B in Fig. 1920.
Fig. 1921 is a transverse section through C D in Fig. 1918.
Fig. 1919, plans of the retort in section, over the top of the retort, the web, and furnace, respectively.

The same letters refer to corresponding parts in all the figures.

E is a hopper containing the coal; F is the discharging-disk; G is the retort; H is a web on to which the coal is discharged by the disk F; I I are revolving drums carrying the web H; K is the furnace; L L the flues passing under and over the retorts, and finally into the main flue; M the shoot into which the coke falls; the end of which may either dip into water or be furnished with a tight door.

1919.

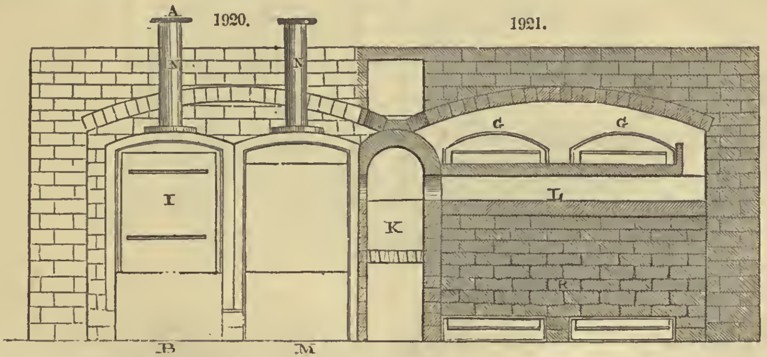


The retort itself, and the chamber in which the drums work, are made of wrought-iron boiler-plates, riveted together so as to be quite gas-tight. The only parts subject to wear and tear are the retort adjoining the flues and the web, both of which are heated; the latter however never becomes so hot that the shape alters. The action of this arrangement is as follows:—

All the coal must be either ground, or beaten small and screened, so that no lumps remain larger than coffee-berries, and a twenty-four hours' charge must be thrown into the hopper and secured by a luted cover. The discharging-disk, which is nine inches in diameter, with six arms, is made to revolve uniformly with the drum below it, at the rate of four revolutions an hour; for this purpose two shafts run the entire length of the retort-beds, on one of which the drums are fixed; on the other are the discharging-disks, connected at one end by a strap. The diameter of the hexagonal drums is so regulated, that the coal which falls on the web from the discharging-lip will at one revolution have passed the entire length of the retort. Fifteen minutes is quite time enough to convert the coal so distributed into gas. Each link of the web is 14 inches long and 24 inches broad, having a surface of 336 square inches, upon which the contents of one partition of the disk will be discharged, viz. a little more than 124 cubic inches of coal in a stratum less than three-eighths of an inch thick. Each successive link receives the same quantity, so that, in one entire revolution of the disk and drum, 745 cubic inches of coal (equal to 21 pounds) are distributed over a heated surface of 2016 square inches, and converted into gas.

Eighty-four pounds of coal will by this process make 450 cubic feet of gas of the specific gravity ·490. It therefore follows, that in 24 hours 18 cwt. of coal will be discharged by each retort, making 10,800 cubic feet of gas, equal to to 12,000 cubic feet per ton.

1920. 1921.



These retorts are considerably more expensive in the first instance than those in general use, but in the end they would be found cheaper. Indeed, the entire arrangement is one of great economy, and by far the most scientific process yet adopted for making coal-gas; it requires no attendance, except that of keeping up the furnace and charging the hopper once in twenty-four hours. No gas is lost, and no tar made. The coke produced is increased in quantity by about 75 per cent., but its quality is not so well fitted for general purposes (although superior for culinary uses) as that produced by the common process.

The power employed for turning the shafts may be a water-wheel, which would be preferable to a steam-engine, unless in large works, where the latter could be employed for other purposes. An overshot wheel, six feet in diameter and nine inches in breadth of float, would drive twelve retorts at the speed required; the water for turning such a wheel for twelve hours may be pumped up by two men in about an hour and a half. This form of retort is in first cost more expensive than others, but it is believed to be in the end more economical.

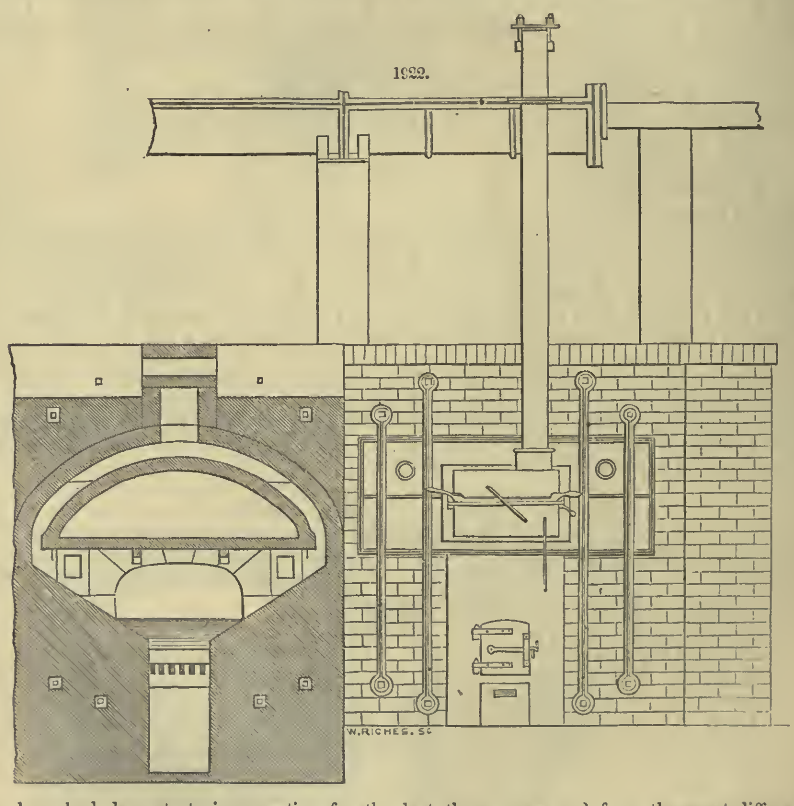
The quantity of gas produced by five D retorts, such as are shown in Fig. 1892, will be about 14,000 cubic feet in twenty-four hours, of specific gravity ·390 or ·400, and the quantity produced by four of the proposed retorts will be 43,200 cubic feet in twenty-four hours, of the specific gravity ·470 or ·490.

All the machinery, except the retorts and webs, will last for years without any repair, except what may arise from contingencies, to which all machinery is subject.

Earthen retorts.—In speaking of clay or earthen retorts, it is necessary to limit our remarks upon them to the *results of practice;* for in many instances, owing to actions not entirely and clearly accounted for, the results given by these vessels differ from those which *theory* in its strict sense would admit as being correct.

One practical point must be observed, that clay retorts of small dimensions are less economical than those of larger size, owing to the great per centage of fuel required to keep them at a proper temperature for decomposing the coal. The advantage of using the latter description of distilling vessel is simply a question of profit and loss, or whether it is cheaper to *burn iron or coal.* The material of which they are formed is a non-conductor of heat, consequently the absorption of caloric is less rapid; and although they retain their heat when a fresh charge is introduced better than iron retorts, yet not sufficiently to bring down the quantity of fuel as low as that required for metal. Notwithstanding this, even small clay retorts are preferred in many places, particularly in Scotland. Mr. James Reid, of the Montrose Gas-works, has favored us with the following description of his earthen retorts:

1922.



"We have had clay retorts in operation for the last three years, and from the great difference in price, compared with that of iron retorts of the same size, and from the immense superiority over metal in working them, we have entirely given up the use of the latter. I tried the clay retorts in the shape of an ellipsis, in the D and circular form. The size I find best adapted to all purposes is eight feet long, fourteen inches diameter, and four inches thick: such a retort costs £2 6*s.*; the pillars or columns for supporting them are 6*s.* each, and each retort finished costs £3 4*s.* The mouth-pieces are cast metal, and fastened to the end of the retorts by bolts and flanches, as in the ordinary description, and jointed with fire-clay and iron cement. The retorts are made in two lengths, and are jointed by a body of fire-clay well diluted with water. The most economical plan for erecting them is to set them, three under one arch, heated by one fire. Their only drawback is, that when the heat is let down they contract unevenly on cooling, and are liable to leak when again required for distillation; they generally last two years."

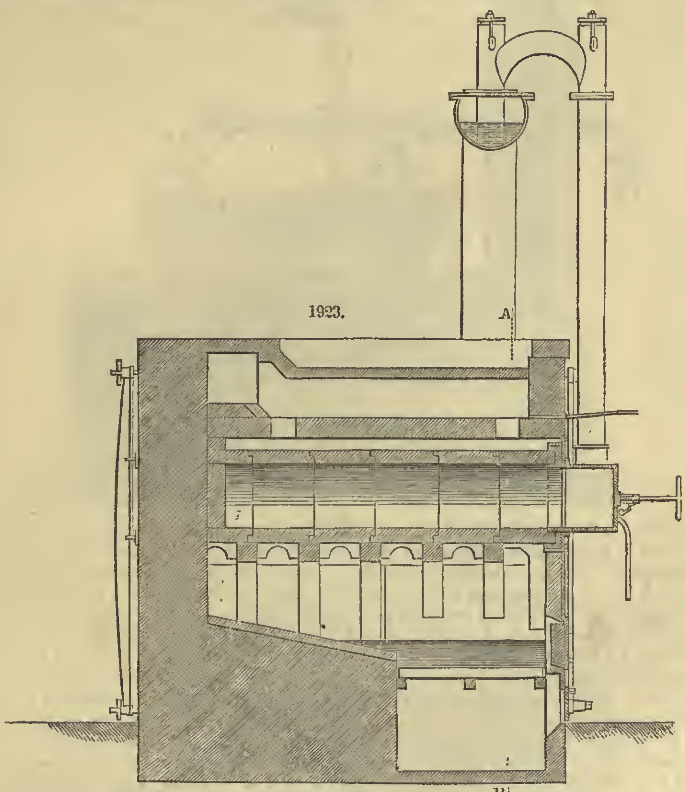
Clay retorts have been used for some years at Wolverhampton with success. The retorts are circular and made in joints of 32 inches long. In several places these retorts are made at the works.

The reader will fully understand their plan of construction from the elevation and sections. Trans-

verse section and elevation, Fig. 1922, and Fig. 1923, longitudinal section, which require no description, except that the bottom is exposed directly to the heat of the fire, and is slightly "cambered," or curved upwards, to enable it with more certainty to retain its form. The cement with which the parts of the oven are jointed is a composition the ingredients of which are not known, but seems to be an excellent substance, and when the interior is coated with it, becomes vitrified and quite gas-tight under considerable pressure.

In England and Scotland the fire-clay retort has superseded the use of metal in no less than forty towns; in some instances it has lasted for the extraordinary period of twelve years. The oven or D-shaped retorts are found to be the most advantageous, being made with a capacity to carbonize one cwt. of coal every hour. They can be constructed either to be heated by coke ovens, or coke furnaces, or by the burning of tar: with coke ovens they are more durable. It appears that clay retorts, when constructed upon such a scale as that given in Fig. 1922, have great power to *retain* their heat when brought to the proper temperature for decomposing the coal, viz. 27° of Wedgewood, and the introduction of a fresh charge is not nearly so much felt by them as by metal. This power of retaining heat is proved by constant practice to produce 1000 cubic feet of gas per ton from the same coal more than the average of the London produce, and the consumption of fuel is not more than 22 or 23 lbs. of coke to carbonize 100 lbs. of Newcastle coal, taking the average of six months' working.

1923.

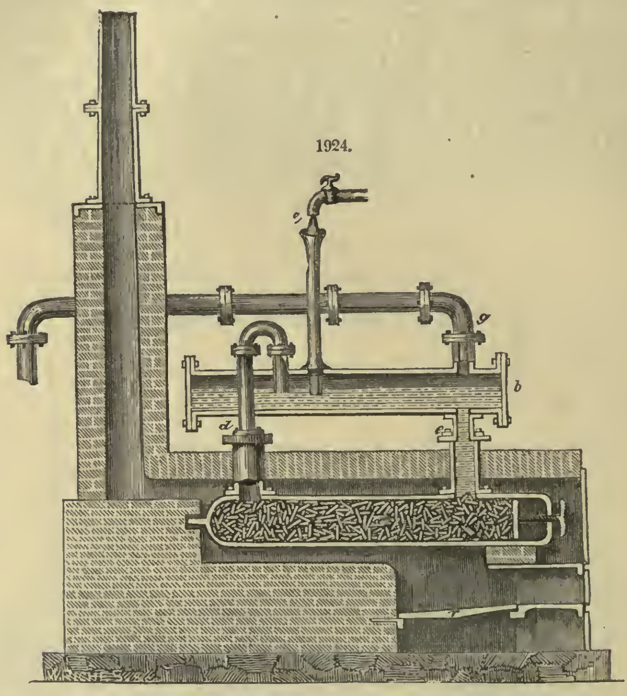


When properly constructed, these retorts are not in any degree liable to fracture or to the escape of gas, but are of such strength as to resist the greatest pressure which is likely to be put upon them. The coke also made by them is invariably of better quality, and produces less breeze or waste.

Oil gas.—It appears, at first sight, both inexpedient and superfluous to distil oil for the production of gas, when we consider that oil can be burnt in lamps without any further preparation, whilst it loses carbon by deposition in the retorts. Purified lamp-oil is consequently never used; but gas can be prepared from impure oils, train-oil, or refuse fat, with as much ease as from the purer kinds. The manufacture of gas is, therefore, under certain circumstances, an admirable means of using up such materials for the production of light, as could not otherwise be employed, or only applied to the lowest uses. The experiments of Henry, which extend also to this part of the subject, show at once the plan that must be adopted upon a large scale. His results are given in the table in the following page; from which it appears that oil gas is superior to that obtained from coal, as is also shown by its density, and that the produce, dependent chiefly upon the temperature, is of the best quality when obtained at a low red heat. This temperature suffices to convert the oil into gas, but is not sufficiently high to decarbonize the gas to any great extent. The apparatus for obtaining gas by the distillation of oil is represented in the following drawing, Fig. 1924. To accelerate the evolution of gas, and shorten the time which the gas already produced has to remain in the red-hot vessel, the retort *a* is filled with bricks, or

lumps of coke, which extend the red-hot surface very materially. The second cylinder *b*, serves both as reservoir and hydraulic main at the same time, and, with this object in view, *a* and *b* are connected in two places *d* and *g*. Oil flows from a large cistern above the apparatus in a constant stream through the tube *c* to *b*, which *b* is thus kept filled up to a certain level. From *b* the oil descends through *e* to *a*, is converted into gas and tar, returning through *d* to *b*. The tube *d* makes a short bend, and just enters below the fluid level in *b*, so that the vapors of the decomposed oil must constantly pass through the reservoir of oil, and deposit their tar. The retort *a* is, therefore, constantly supplied, not only with oil, but with a mixture of oil and tar, in such a manner, that all the condensed products return to the

1924.



retort together with a fresh quantity of oil, until they are completely converted into gas. If the experiment is made in a long tube, inclined at the hinder part, whilst the front is kept cool, hardly any tar will be produced. The gas which collects above the oil in *b*, passes on through the tube *g*. As the objections raised in the case of coal gas do not here occur, cast-iron retorts are solely used in oil gas works, with the same firing in other respects, *r* being the grate. According to trustworthy statements, 1 cubic foot (= about 4 gallons) of oil produce 600 to 700 cubic feet of gas, which is equivalent to from 90 to 96 per cent. by weight; the remainder is carbon, which is deposited between the coke or bricks, and some unavoidable loss. The production of oil gas is a continuous process, and thus differs from the distillation of coal. The retorts only require opening now and then, for the removal of the deposit of graphite. Vapors of the same composition and properties are found in oil gas, as in coal gas. Thus, according to Hesz, all the volatile empyreumatic oils, which occur mixed with each other in tar from oil, have the same composition per cent. as olefiant gas. Faraday had previously observed in England, where oil gas was compressed for technical purposes with a pressure of 30 atmospheres, that these vapors were condensed to a fluid, of which 1 part occupied the space of 7500 parts of gas.

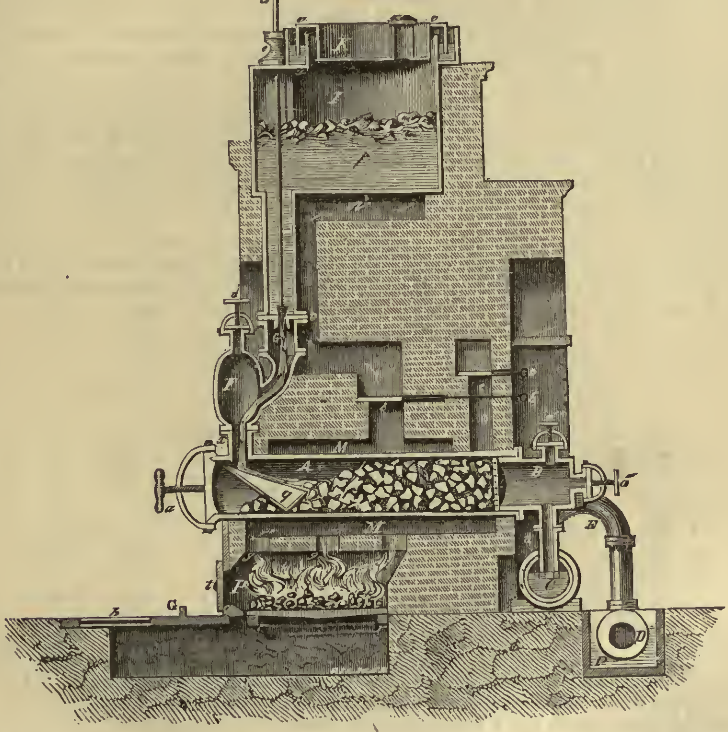
Substances distilled.	Temperature of the Distillation.	Specific gravity of the gas.	Absorbed by chlorine.	Light carburetted hydrogen.	Carbonic oxide.	Hydrogen.	Nitrogen.
			In 100 parts of illuminating gas.				
Oil . . .	Bright red heat	0·464	6	28·2	14·1	45·1	6·6
	Ditto	0·590	19	32·4	12·2	32·4	4
	Lowest possible temperature .	0·758	22·5	50.3	15·5	7·7	4
Train-oil	Low red heat	0·906	38	46·5	9·5	3	3

Resin gas.—If resin (colophony) were usually fluid, instead of being solid, there would be no difference in the mode of obtaining gas from it to that practised in the oil-gas manufacture; as this, however, is not the case, it becomes necessary to render the resin fluid by some suitable means, that it may be easily supplied to the retort. The volatile oil from tar is frequently used for this purpose.

The flame from the retort fire, before escaping by the chimney, is caused to heat up a vessel containing resin. As this melts, it trickles through a sieve, into the second division of the vessel, leaving the impurities and the solid portion behind, where it is mixed with an equal part of the oil of resin (tar). Thus a solution which will no longer solidify is obtained, and with it the retort is supplied, as with oil in the former case. When the gas has parted with its condensible vapors in the coolers, it is in a fit state for consumption, no further purification being required, as is likewise the case with oil gas.

One of the best arrangements for resin gas, and which has stood the test of practice, is that which has been extensively carried out by Chaussenot, and is shown in Fig. 1925; the resin is here melted by itself, and the oil of tar collected and disposed of as a secondary product. The draught to the fireplace P is regulated through the ash-pit by means of the plate Q, which can be moved horizontally backwards and forwards in the groove *h*. The air passing from below through the grate *r r*, and the fuel, creates a powerful flame, which passing, in the first instance, through the apertures *g g g* in the roof, plays round the retort A, in the space M, and then, before reaching the chimney, heats the vessel I, containing the resin, by means of the flue N N. If this vessel requires filling, the fire is shut off from N, by the damper *b*, and is allowed free egress at the aperture O, by drawing back the damper *c*. Both the dampers are worked by iron rings and rods from without. In Chaussenot's apparatus, it is not necessary to dissolve the resin in tar-oil, because the vessel I, in which the resin is melted, and the conducting tube H, being constantly surrounded with hot air, no solidification of the melting resin at the bottom *f* need be apprehended. Combustible gases are generated by merely melting the resin, which may possibly endanger the whole apparatus. To avoid such contingencies, the edge of I is furnished with a groove filled with water *u u*, into which the lid K dips at *v v*, and is consequently secured by a water-valve. By means of the appendage *y*, the vapors can be conducted into the chimney, or under the grate. The melted resin flows consecutively through H G and *x*, into the retort A. Between

1925.



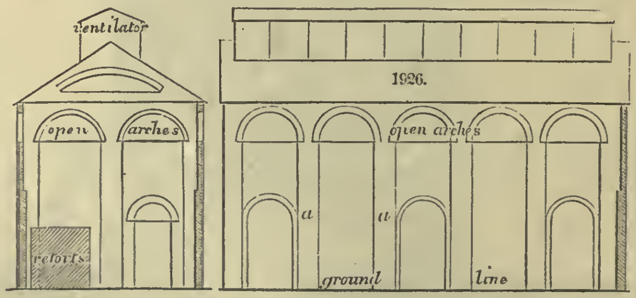
G and H is a plate *o*, with a funnel-shaped aperture in the middle, in which the conical end of the rod *d* is movable. If this is raised through the stuffing-box *e*, the retort A receives a larger flow of melted resin; if it is pushed down the stream diminishes, or the flow ceases entirely. The resin flowing from *x* is carried to that part of the retort containing the coke, by means of the inclined plate *g*. The coke is prevented falling into the neck of the retort by the grating *l*; here, too, the gas escapes through a tube downwards to the tar cistern C, and from thence through E to the cooling pipe D, which is immersed in water in a long trough P. C is constantly nearly filled with tar, that the mouth of *w* may always remain immersed; this, therefore, dips into C, whilst the gas-pipe E, behind the sectional level in the drawing, only just passes through the material of the main C. The neck F, situated above *x*, has a small appendage *a′*; this, as well as *a″* and *a‴*, is constantly immersed, and all three are used only for introducing iron rods in cleansing the approaches to the retort; *a* is a similarly constructed appendage for screwing up the lid of the retort; *a a′ a″* and *a‴* are all furnished with iron semicircles and

screws, for forcing iron plates flat against the apertures. In such a furnace, therefore, distillation goes on continuously, until the deposition of carbon renders a renewal of the coke necessary. Resin gas is not so highly illuminating as oil gas, and is of about the same quality as coal gas; it is used in many towns, as in Frankfort-on-the-Maine, Antwerp, &c. 14 to 23 cubic feet of gas are obtained from 1 lb. of resin.

Gas from soap-water.—Few cases are adapted to give so favorable an idea of the practical value of gas illumination, as the process carried out at the works of Houzeau Muiron, at Rheims, where very good gas is obtained from refuse which previously cost something to throw away, and which now is a source of profit to the manufacturer. This refuse is the soap-water, in which woollen stuffs have been freed from fat. Besides the unchanged fat with which those goods are charged as they come from the loom, the soap-water contains a solution of oleate and stearate of soda, and compounds of the same acids with lime in suspended flakes, and lastly, animal matters extracted from the wool. From all parts of the town the soap-water is collected, and brought to the reservoirs of the works, where 300 cwts. at a time are treated with 2 per cent. of sulphuric acid, (or twice as much hydrochloric,) mixed with equal parts of water. After the lapse of 12 to 18 hours, complete coagulation is effected. The water contains Glauber's salt (sulphate of soda) in solution; a little gypsum is formed at the same time, and an impure gray fatty matter rises to the surface. This consists of the fatty acids, oil, and animal matter with much water: the greater part of the latter has already been mechanically separated, and the remainder is removed by melting in copper vessels; the contents are then drawn off into a second boiler containing some sulphuric acid to effect a clarification. The filtration which follows affords a clear oil, and this gives with crude soda (containing sulphuret of sodium) a very tolerable soap, whilst sulphuret of iron separates, together with a black solid residue, containing much fat for distillation in the gas retorts. The process of distillation is like that practised with resin: the tar produced the first day is used on the morrow to dissolve and render fluid the solid residue, and so on. The ohm (= about 30 gall.) of soap-water costs 28 kreuzers, (= about 18 cents.)

Gas from animal matter.—In the distillation of animal matters, bones, flesh, &c., as it has long been practised for the production of bone-charcoal and bone-black, tar (stinking oil, Dippel's animal oil) and gases are generated. The illuminating power of the latter has latterly attracted the attention of manufacturers. Seguin, in particular, has carried on the process on a large scale, making use of the gases. The material, for instance, the flesh of dead animals, contains 60 per cent. of water, which must be removed by drying before being placed in the retorts, and the latter should be kept at a cherry-red heat The sulphur (a constituent of albumen, fibrine, &c.) is chiefly found in the gas as sulphuret of carbon, the nitrogen of the flesh as carbonate of ammonia. After being properly cooled, the gas is first passed through a solution of chloride of calcium, where carbonate of lime and sal-ammoniac are formed, and from thence through tubes containing lumps of sulphur, which condense the sulphuret of carbon to the fluid state, and dissolve in it. The latter would be converted in the flame into sulphurous acid and carbonic oxide.

Retort-house.—The adjoining cut, Fig. 1926, represents a retort-house built of brick, for coal gas, upon the most simple construction, and well adapted for a town requiring 70,000 cubic feet of gas for the supply of each night in the winter season. Being without coke-cellar, the charges must be drawn into wrought-iron barrows, the contents wheeled into the open air and spread abroad to cool.



The outside walls are calculated to give the greatest security with the least possible material. The piers *a a* are 18 inches thick at the base, projecting 4½ inches (on the outside) from the brickwork filling the space between them. Half way up the walls there is a 4½-inch offset, which leaves the thickness of the panels 14 inches below, and 9 inches above the offset.

The roof is of wrought-iron; the ventilator is of wood.

The retorts were set five in one oven, making forty retorts, which will allow two extra benches for repairs.

In twenty-four hours, thirty working retorts will carbonize 240 bushels, or 180 cwt. of coal, and produce 78,000 cubic feet of gas. In some places, where little gas is required in the summer season, one-half or even the entire number of retorts may be set three to one oven with economy.

In the example, Fig. 1927, advantage was taken of sloping ground to form a coke-shed, which saved a considerable quantity of brickwork. The charge, as it was drawn, fell through the space in front of the retorts, and was carried by an inclined plane into the shed behind.

This house is considerably larger than that described in the last example, and is furnished with a coal-store. It may perhaps be as well to state here, that coal from which gas has to be distilled should if possible be always kept under cover, because, when moisture is present, the hydrogen arising from

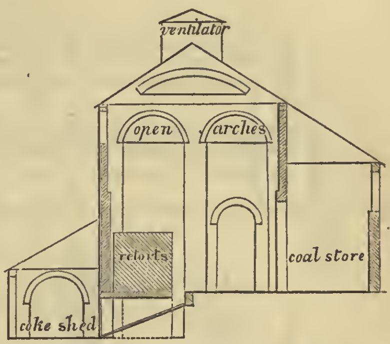
the decomposition of water will deteriorate the quality of the gas. It is, therefore, a matter of economy to construct a sufficient shed to preserve the coal in a dry state.

The house contained 55 retorts, allowing two benches of five retorts each for repairs. The coal carbonized by the remaining 45 retorts was 360 bushels, or 270 cwt. in twenty-four hours, producing 117,000 cubic feet of gas.

The cost of these buildings will depend upon the price of brick, lime, labor, &c., and will vary in different localities.

Chimneys.—The draught absolutely required for the proper combustion of the fuel beneath the retorts is little; indeed, that usually given to a common coke-oven would be sufficient. It is necessary to build a high chimney, however, to carry off the smoke, which, if not allowed to spread, would become a nuisance to the neighborhood. The height of a chimney does not decrease the *quantity* of smoke, but distributes it over a larger surface and causes less inconvenience.

1927.

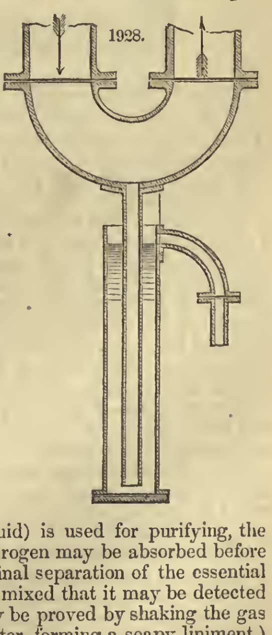


To obviate the excess of draught, it is advisable to make an opening into the shaft communicating with the external air. The dampers of the retort-flues might be used to adjust the draught, but this would be relying too much upon the workmen. It often happens, if there is no check, that during the night the heat of the ovens will be neglected, and suffered to fall below the proper temperature; and then, to make up, the dampers are opened and the furnaces forced, to the deterioration of the retorts, the waste of fuel, and the production of inferior gas. When there is an air-opening into the shaft this cannot be done, and there will therefore be less danger from such carelessness.

With this precaution, the chimney may with advantage be built seventy feet high, even for a small number of retorts; but the height of the shaft must always be regulated by the description of property surrounding or in the vicinity of the works.

Purifiers.—The gas, when it leaves the retorts, retains its impurities, and in this state is quite unfit for illumination. The impurities are bituminous vapor, ammoniacal gas, essential oil, and sulphuretted hydrogen; the processes adopted for removing these are partly mechanical and partly chemical. The first operation is the condensation of the volatile portions, which is effected at different places in different ways. The condensers generally adopted either consist of a series of pipes arranged in the manner of a distiller's worm, or of a number of chambers contained in a tank, and surrounded by cold water at the lowest points of these vessels siphons are attached, sealed by dipping them into tar to a sufficient depth to prevent the gas from escaping, and through them the condensed bituminous and ammoniacal vapors pass away to the cistern constructed to receive them in the forms of tar and ammoniacal liquor

1928.



The same tank serves to contain both, the difference of their specific gravities keeping them separate; the ammoniacal liquor, being the lightest, swims on the surface of the tar. The tank is generally sunk below the surface of the ground; the respective heights of the two fluids are registered by floats and gages, and, when found necessary, are pumped out. If there be no sale for the tar, it is burned beneath the retorts, and the ammoniacal liquor is either evaporated in the cast-iron pans placed under the furnaces for that purpose, manufactured into the carbonate and muriate of ammonia, or used as manure. The simplest and best condenser is formed of a few upright pipes. Their number and length being regulated by the quantity of gas required to pass through them, ten feet run of pipe for every 10,000 feet of gas is ample; in height they may be equal to that of the wall of the retort-house, for the convenience of placing a tank on the roof to supply them with water. At the bottom of each bend is a siphon, similar to that represented in the annexed woodcut, by which the condensed vapors before mentioned are conveyed to separate vessels, the fluids passing away being of different values, (that from the last siphon is the most valuable.)

These pipes must be kept wet in warm and dry weather by small streams of water running on to them from a tank placed at the top of the retort-house. The quick evaporation of this moisture will keep the pipes much colder than if they were completely immersed in water If after condensation "dry lime" (the term "dry lime" is used in contradistinction to lime-water, the first being simply a hydrate, the latter holding lime in suspension with a large quantity of fluid) is used for purifying, the gas must pass through a wash-vessel, that a portion of sulphuretted hydrogen may be absorbed before the gas comes in contact with the lime in the purifiers; and to effect a final separation of the essential oil, ammoniacal and carbonic acid gases, the essential oil is so intimately mixed that it may be detected in gas after it has passed through a pipe a mile long. (Its presence may be proved by shaking the gas with a little alcohol contained in a bottle; the oil will unite with the latter, forming a soapy liniment.) A wash-vessel is shown in Figs. 1929, 1930, and 1931: A is the inlet pipe for the gas, which displaces a column of water about three inches high, and passes first through the openings *b b b* and at the sides of the wrought-iron box B, then through the continuous opening or slit C C, (which must be equal in area

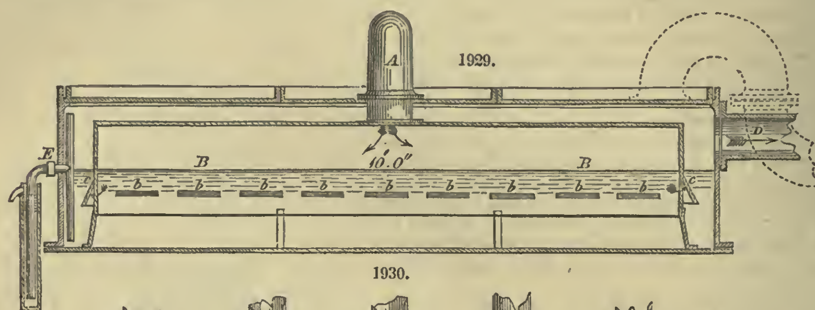
to that of the inlet and outlet pipes, viz. in this example, 50·265 square inches, the diameter of the pipes being eight inches,) and finally through the water. The use of the opening C C is to divide the gas into small portions and distribute it over a large surface. The more minutely it is divided, the better will the wash-vessel effect its object.

D is the outlet-pipe.

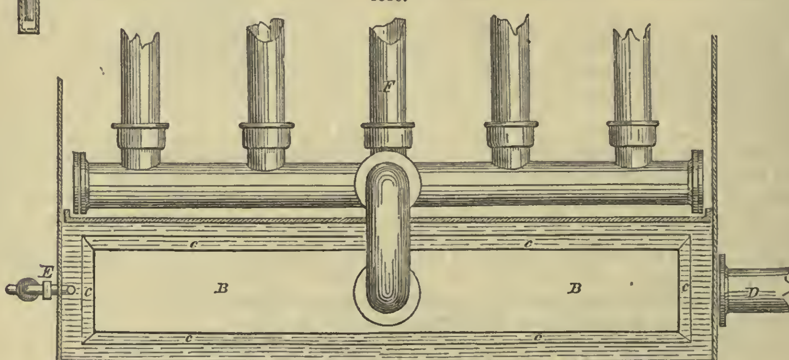
E is a siphon, for maintaining the water at a certain level; the part which enters the tank is conducted to the bottom, in order that the sediment may run off. The upper end of this dip-pipe is open, or it would otherwise form an actual *siphon* and drain the tank.

F is a portion of a condenser, called by workmen a "gridiron condenser," which, when separators are used, may be dispensed with.

1929.

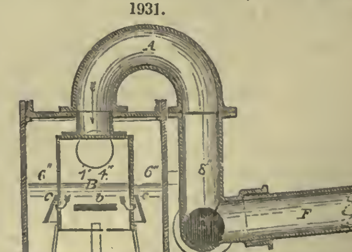


1930.



After this last process, the gas is in a state to come in contact with the dry or hydrate of lime to be purified, which is much the best for that purpose, as it is attended with less nuisance, less pressure, (which is also of importance,) and the sulphur which has united with the lime may be sublimed from it by putting the *spent* lime from the machine into burnt-out retorts kept at a heat just red by daylight, with the refuse coke-dust and cinders, for which there is no sale. The sulphur thus produced is a marketable commodity. The larger the surface of dry lime to which the gas is exposed the better; for if it be allowed to pass through the stratum with much velocity and in an undivided stream, it will work a passage in such a way that a great bulk will not be purified at all, for of course it will pass through that part where it meets with the least resistance: from this not having been understood or attended to, many superintendents have abandoned the use of dry-lime purifiers. The quantity of lime required for purifying coal-gas by the above process will depend upon the quality of both the lime and gas. One bushel of quick-lime will suffice in some places to purify 10,000 cubic feet of gas, while in others twice that quantity will hardly serve. By being slacked and reduced to a proper consistency for use, its bulk will be more than doubled; two bushels of this hydrate will spread over a surface of 25 square feet, 2½ inches deep, which is about the thickness found in practice to be the best.

1931.



In Figs. 1932 and 1933 are represented an elevation and plan in section of one of a series of three "dry-lime" purifiers, through which the gas passes successively; in other words, they are "worked together," and, though separate, may be considered as one machine.

A is the inlet pipe from the wash-vessel, entering at the bottom of the first purifier.

B is a plate of sheet-iron, about two feet square, placed over the mouth of the inlet-pipe, to separate the stream of gas in some degree, as well as to prevent any lime from falling into the pipe.

C C C are the layers of hydrate of lime, spread upon screens formed of an outside frame, and a number of round rods or wires about 5-16ths of an inch in diameter, stretched across them in one direction, to afford greater facility for clearing, with a small interstice between each. These screens are placed

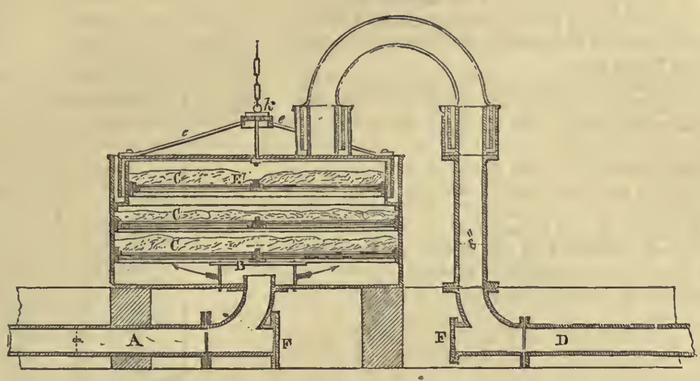
one over another, in three tiers, from six to eight inches asunder; each tier may consist of four screens for the convenience of lifting them out and replacing them.

D is the outlet-pipe leading to the second purifier. This arch-pipe is made of thin plate-iron, sealed at each end by a water-joint; because, when the lid has to be lifted, this arch-pipe must be removed, and any other kind of joint would be troublesome.

E is the lid of the purifier, also sealed by a water-joint; *e e* are round 5-8ths rods, keyed at one end into the keep-ring *k*, and riveted to each corner of the lid at the other; a chain is hooked on to the ring *k*, and passed over a pulley to a balance-weight, by which, and the rods just mentioned, the lid is lifted.

F F are blank flanches or bonnets, through which, when removed, the pipes are cleared from any deposited impurity.

1932.



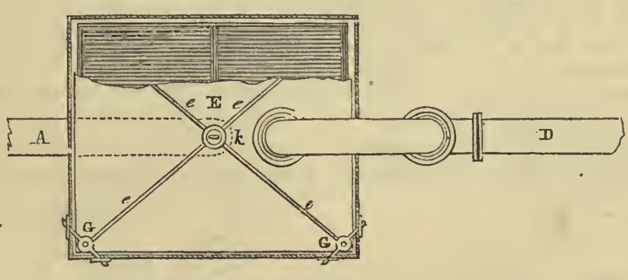
G G are clamps, to keep the lid of the purifier in its place.

A is the pipe leading from the wash-vessel into one partition of the hydraulic valve, which shall be described immediately.

B is the pipe leading to the three purifiers C D E in action, and rising into the same partition of the valve as B.

F is the pipe leading the purified gas back to another partition of the valve.

1933.



G is the pipe conveying this gas to the meter and gasometers; the connection between the two last-named pipes is formed in the same way as that between the pipes A and B. It will be evident that the lime contained in the first purifier will be spent or saturated before the other two, and that contained in the third will be comparatively untouched. At the expiration of twenty-four hours C D and E must be shut off, by changing the divisions of the hydraulic valve to the situation shown by the dotted lines in the figure representing that valve, and turning the gas through H I K, having previously been put in readiness; at the instant of turning the valve the gas will pass through both sets of purifiers, all the communications being open.

When the covers of C D and E are taken off, remove the screens from C, and place those from E in their stead. The lime from C is quite expended, and must be either heated to sublime the sulphur, or laid aside until it can meet with a sale as manure, or be otherwise disposed of. That from D may be spread for a time in the open air, (if there be room in the works,) and in a week or two it will be fit to use in the first purifier. After renewing the lime in the second and third purifiers, replace the covers, and they are again ready for action. The same operation is repeated when H I and K are spent.

Fig. 1934 represents the hydraulic valve just mentioned.

A is a cast or sheet iron tank, three feet diameter and two feet six inches deep, generally filled with tar to within six inches of the top.

B is a light sheet-iron or tin gasometer-shaped vessel of less diameter, divided into three partitions by the plates C D and E, of less depth than the rim.

F is the pipe from the wash-vessel or condenser.

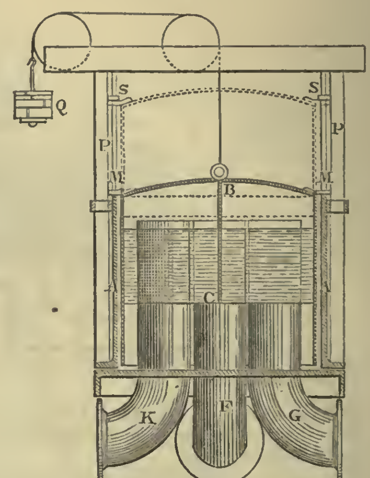
G is the pipe leading to the first set of purifiers.

H is the outlet or return pipe from them.

I is the pipe leading to the meter and gasometers. These pipes, in the present position of the valve, are all in action.

F and G, being in the same partition, communicate with each other, as do H and I, for the same reason. When the purifiers have to be changed, the vessel B is lifted up, until the bottom of the partition, at C in the elevation, Fig. 1933, clears the pipes, the outside rim remaining immersed in the tar, (the stops S on the guide-rods prevent it from being lifted too high,) and turned partly round until it occupies the position shown by the dotted lines in the plan, Fig. 1934½. The length of each dot N through which the guide-rods M pass, mark this position and effectually prevent mistakes, for the vessel cannot be turned the wrong way.

1934.



K and L are the pipes connected with the second set of purifiers thrown into action and into communication with F and I, when the vessel B is shifted to the position shown by the dotted lines in the plan.

P is a wooden frame supporting the pulleys and balance-weight Q to assist in lifting the vessel B, which, while in action, is kept from rising with the pressure of the gas by a bolt.

In preparing the lime for the purifiers, it ought to be beaten, well sifted, and water added, until, by compression in the hand, the lime will just adhere; if any lumps remain, their outside only will be acted upon; when broken, they will be found untouched in the inside; and although such lumps may be used again, it is always better to systemize the process in the first instance, and prevent even the smallest waste.

Lime-water purifier.—Fig. 1935 is an elevational section of a lime-machine, and Fig. 1936 a plan through *a b* in Fig. 1935.

A is the inlet-pipe through which the gas passes into the chamber B, which is four feet diameter, jointed to the lid of the purifier, and supported upon two cast-iron beams C. On to the bottom flanch of this chamber a circular ring of thin wrought-iron plate is riveted, of such diameter that its outside rim will be within five inches of the tank of the purifier.

D is a hoop supported from the tank by bolts *d d*, etc., having its upper edge level with the before-named plate, and its lower edge four or five inches below it. The space left between this hoop and the ring is three-eighths of an inch, through which the gas (after having overcome the pressure of the column of water contained in the tank, plus the pressure in the gasometers) will pass, and bubble up through the lime-water.

E is an arm made to revolve on the spindle S: the parts *e e* of this arm continue through the aperture and over the ring, serving to keep the lime from settling or obstructing the passage of the gas.

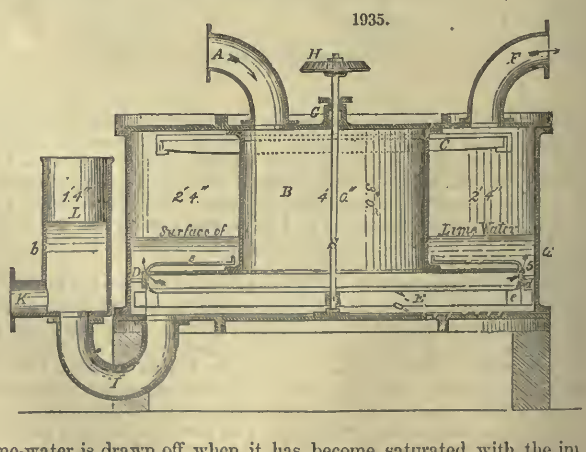
F is the outlet for the purified gas.

G is a stuffing-box, through which the spindle S passes.

H is a miter-wheel, connected to a water-wheel or steam-engine for turning the spindle.

1934½.

1935.



I is a pipe, through which the lime-water is drawn off when it has become saturated with the impurities of the gas. It will be observed, that by this contrivance the water can be completely drained off, by opening a slide-valve bolted to the flanch of the pipe K, without suffering the gas to escape along with it, because a column of water will remain in the tube I equal to the height of the bottom of the tank, measured from the inner radius of the curve of the tube, viz. twelve inches, which is always

more than sufficient to overcome the pressure of the gas in the purifier when the valve on the inlet-pipe A is closed, which should be done before that at K is opened.

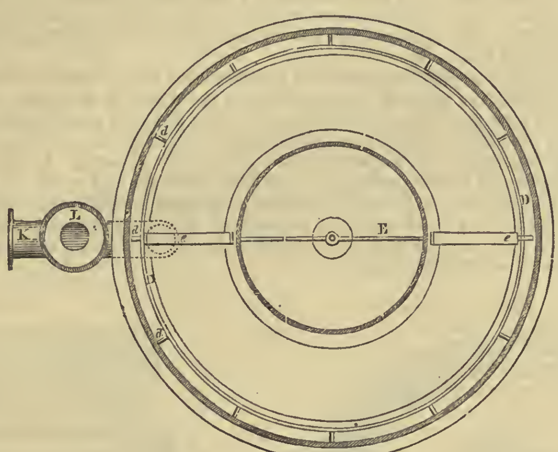
L is a cylindrical vessel, open at the top, for filling the purifier; it also serves to show the quantity of water required; when the machine is at work the column contained in the vessel will be as much higher than that in the tank, by the pressure of gas in the gasometers, usually about three inches.

The lime-water may be mixed in a cistern, and drawn off by a hose into any of the machines, care being taken to keep the mixture well agitated while passing. The proportions are one measure of paste-lime to three of water; that is, to every five bushels of paste-lime about 120 gallons of water must be added. The size of the lime-machines ought to be so regulated that they will contain sufficient lime-water to purify the quantity of gas made in twenty-four hours, without having occasion to fill them higher than the water-line shown in the engraving.

Four lime-machines are necessary, two being in action and two out, alternately. When that machine is spent through which the gas first passes, shut it off, and open a third, leaving the second to perform the duties of the first, and so on.

The quantity of lime required for the complete purification of coal gas varies very much with the quality of the lime and the gas; that coal which produces the greatest volume of sulphuretted hydrogen from the presence of iron pyrites will require the most lime. As the best means for arriving at a proper practical conclusion, we annex the quantities used at different gas-works in various places.

1936.



At the Imperial Gas-Works, London, one bushel of quicklime purifies on an average 10,000 cubic feet of gas, the price of lime being 7*d.* per bushel. The lime is used both as a hydrate and in the fluid state, in the following proportions:—For the purification of 1,000,000 cubic feet, the produce in the winter season of twenty-four hours, eighty bushels mixed as "dry lime," and twenty bushels mixed into a fluid: this quantity performs its part thoroughly.

At Cheltenham 1½ bushel of quick-lime, reduced to the state of a hydrate, will purify 10,000 cubic feet of gas perfectly: cost per bushel from 5*d.* to 6*d.*

At Birmingham the purification of 1000 feet costs, in lime and labor, from 1¼*d.* to 1½*d.*, but in reality not nearly so much, as the refuse is sold for two-thirds the original cost of the lime. Lias lime is used, and "dry purifiers."

With the dry-lime purifiers at Chester, 1 cwt. 2 qrs. is required to purify 10,000 cubic feet of gas. The Welsh lime is used, its price being 13*s.* 4*d.* per ton; therefore the purification of 10,000 feet will cost 12*d.* without labor, which is about the average cost.

In making the dry-lime purifiers, that they may present a sufficient surface to the gas which passes through them, an excess, rather than a smaller area, should be given. A bushel of lime, when reduced to the state of a hydrate, contains very nearly 4500 cubic inches: allowing that this quantity will purify 5000 cubic feet, it follows that 12·5 square feet of screen surface is required, the depth of the lime being 2·5 inches.

For retorts calculated to produce 300,000 cubic feet of gas in twenty-four hours, the purifiers should present a surface of at least 750 square feet. If three machines are worked together, each containing five screens, their dimensions may be 8 feet 6 by 6 feet, and 3 feet deep, four bushels of hydrate of lime being spread on each screen. The surface presented by three machines like Fig. 1932, is 324 square feet: they were erected for an establishment producing 130,000 cubic feet of gas in twenty-four hours.

The work performed by a lime-water purifier is generally computed by its contents in gallons, and the head of water or pressure opposed to the passage of the gas through it. Taking the latter at a constant quantity of eight inches, the computation is easy. 4500 cubic inches of hydrate of lime, (which has been before stated is the quantity produced by reducing one bushel or 2150 cubic inches of quick-lime,) mixed with forty-eight gallons of water, will purify 10,000 cubic feet of gas, if properly applied. In the example at Fig. 1935, the lime machine contains 316 gallons, which will hold in solution thirteen

bushels of hydrate of lime, and purify 65,000 cubic feet of gas. Two of these machines will therefore do the same work as the three dry-lime purifiers before mentioned, viz. 130,000 cubic feet.

Notwithstanding, however, that the quantity of lime required may be well known, it is necessary to *test* the gas in its progress through the various purifiers. A saturated solution of the acetate of lead in distilled water is an excellent test, detecting the presence of the minutest quantity of sulphuretted hydrogen, and more convenient than the carbonate, from its complete solubility. Test-papers may be printed in the following form:—

Station and Date.

Crude Gas.	1st Purifier.	2d Purifier.	3d Purifier.

Lime machine having been charged —— hours with —— bushels of —— lime.

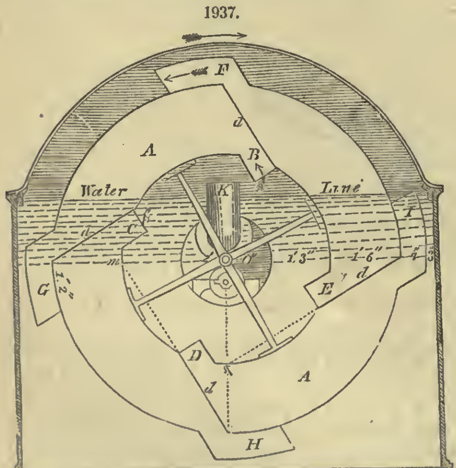
Fill a bladder, furnished with a stop-cock, full of gas from the main, before it enters the purifiers, and also one from each separate purifier, and let the bladders be labelled; with a camel-hair pencil paint the square marked crude gas with the test solution, and force the gas from the proper bladder upon it while wet; the paper will immediately be turned black: then paint the square marked 1st purifier, and force the gas into it, and proceed in like manner with the two others: the paper in the fourth square ought not to be discolored. The squares must not be moistened at once, because the first impure gas would in that case blacken them all.

Lime for the purpose of purifying coal-gas should be free from foreign matter. That which slackens the quickest, and produces the greatest heat during the operation, is the best. When dissolved in diluted muriatic acid it should not effervesce, and should, when perfectly pure, leave no insoluble residue.

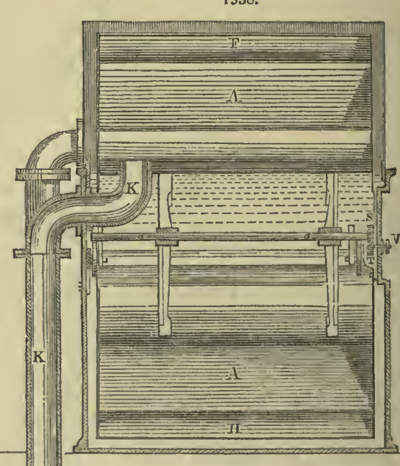
Gas-meter.—Before passing the purified gas to the gasometers, it is necessary that it should be measured and its quantity registered, which operations are effected by the *meter*. Of this machine there are two kinds,—the *station-meter*, for measuring the total products of the coal at the works before it is supplied to the mains; and the *consumer's meter*, for measuring small quantities as supplied to individuals.

Station-meter.—Fig. 1937 is a front elevation in section. Fig. 1938 is a side elevation, also in section, of a station-meter of the capacity of 200 cubic feet, by which 300,000 cubic feet of gas may be measured and registered in twenty-four hours.

1937.



1938.



The principal part of the machine consists of a hollow drum of thin sheet-iron A A, revolving upon an axis *a*, and divided into compartments, so arranged, that, as the gas enters, it shall in revolving successively fill all the chambers, pass through them, and be discharged measured.

The part of the drum which contains the gas is in the form of a concentric ring, one foot six inches broad, and six feet deep, and seven feet six inches in extreme diameter, which will be understood by reference to the engraving. The plates which form the sides are of the same outer diameter as the drum, viz. seven feet six inches, but are two feet nine inches broad; they will therefore project within the smaller diameter, leaving the centre circle (through which the inlet-pipe K passes) two feet in diameter. The surface of the water contained in the drum and outside tank of the meter, is four inches above the upper circumference of this centre circle, when the drum is in its place; so that the communication between the outside and inside of the drum is cut off by a head of water of that height, and continues to be so in every part of the revolution. It is evident, therefore, that the gas must enter any chamber having its inner hood above the surface of the water.

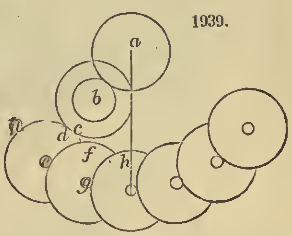
B C D E represent the inner hoods, and the direction of the gas from the inlet-pipe is shown by the

small arrow at B. As the chamber fills with gas, it displaces the water, and causes the drum to revolve. Before B dips into the water, the hood C rises above the surface, and opens a communication for the gas into its chamber; and so on with D E, when it will have completed one revolution and measured 200 cubic feet.

The same action that allows the free passage of the gas *into* the chambers causes it to be expelled *from* them through the outer hoods F G H I, in the direction of the arrow at F: each of these outer hoods is sealed alternately in the same manner as the inner hoods, and opened for the passage of the gas from them, by one constantly being above the water-line. The direction in which the drum revolves is marked by the arrow over the top of the case.

The bevels of the division-plates *d d* are arranged so that they will enter the water without effort. The axis *a a* on which the drum revolves is supported on friction rollers; on the front end of this axis a spur-wheel S is fixed, working into another wheel T, having half the number of teeth; at every half revolution of the drum it will therefore make an entire revolution; its spindle passes through a stuffing-box, and is furnished at the opposite end with another wheel V, which marks 100 feet on the index. From a pinion on the spindle of this last wheel another wheel is worked, having ten times the number of teeth on the pinion, which will therefore mark thousands. This last wheel is again furnished with a pinion and works into a third wheel, which will mark tens of thousands, and so on; the quantities marked on the dials increasing in a tenfold ratio up to hundreds of millions, or higher if thought necessary.

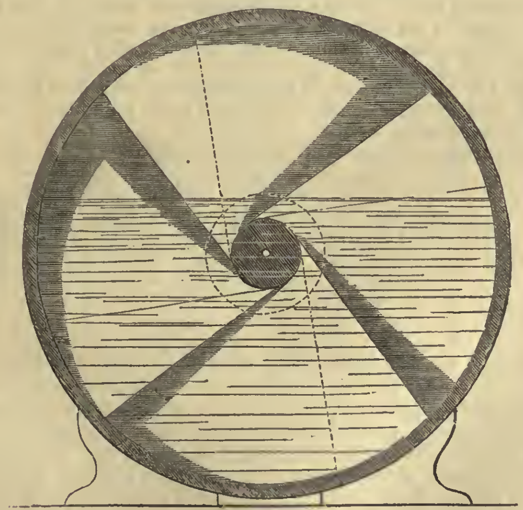
1939.



The entire train of wheel-work is shown in Fig. 1939, where *a* is the first spur-wheel, working upon the main axis; *b* the second wheel, both being inside the meter-case; *c* is the wheel on the opposite end of the shaft of *b*, which projects through a stuffing-box on the case, in order to communicate motion to the train of wheel-work, which must of course be on the outside of the meter-case; *d* is the wheel driving the hand which marks hundreds on the index, and having 100 teeth, (*c* has likewise the same number of teeth;) *e* is the pinion on the wheel *d*, having ten teeth; *f* is the wheel driving the hand which marks thousands on the index, having 100 teeth, and driven by the pinion *e*; *g* is the pinion of the wheel *f* driving *h*, which marks tens of thousands on the index: and in like manner any quantity may be registered. If it be required to register units, (and in smaller meters it is useful,) the first wheel *d* is made to drive a pinion *p*, having ten teeth, to the spindle of which the hand marking units is attached.

The consumer's meter is constructed upon precisely the same principle as that shown in Fig. 1937; but the partitions of the drum are differently arranged, and placed in such a manner, that, as they reach the water, the surface presented shall be as small as possible, or the resistance offered shall be so gradual that the stream of gas flowing through the machine is uniform and constant. This is necessary in a meter from which any number of lamps are immediately supplied; because the most minute diminution or increase of the volume of gas flowing to them would cause a variation in the light, and produce an oscillation. In a station-meter the intervention of the gasometer will remedy this defect. A variation in the arrangement of the drum, therefore, is a matter of necessity.

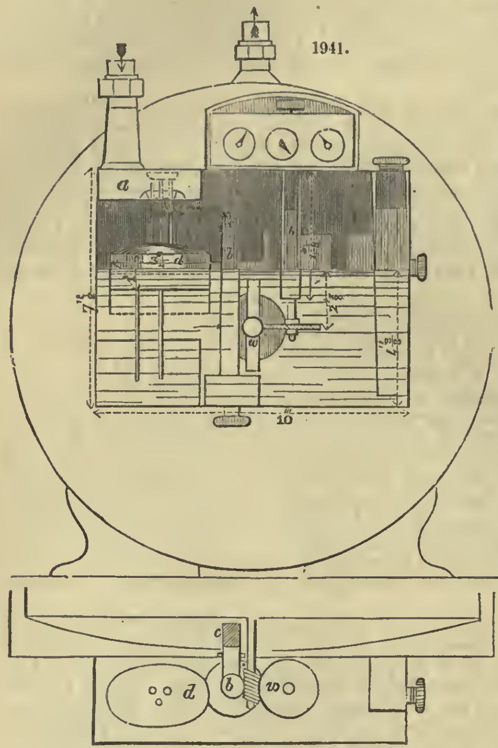
1940.



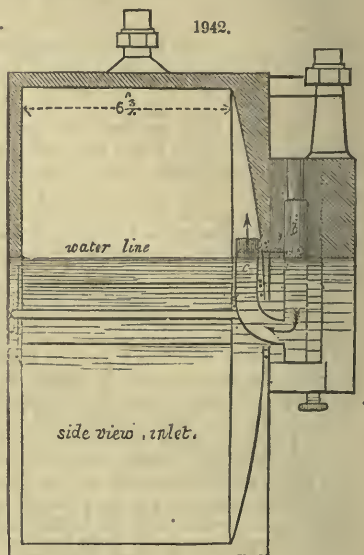
As in the former case, the outer circumference or rim of the drum is divided into four partitions, separated from each other by partition-plates, not running across directly at right angles with the face, but bevelling from the plane of the water, meeting the wrap of the opposite hood. The sides of these partitions are also bevelled; the space left between each plate forming, on one side of the drum, the

inlet, and on the other side the outlet for the gas: the area of the latter being greater than the inlet, to insure perfect freedom of action. The dotted lines show the wrap of the hoods. Fig. 1940 represents a view of the front or inlet side of the drum, with the convex cover removed. The outlets will present the same appearance, but of course reversed. By referring to Figs. 1941 and 1942, the remaining parts will be

1941.



1942.



understood. The direction of the gas is marked by arrows. The box *a*, in which the inlet-valve is contained, is soldered tight, having no communication with the rest of the case, except through the valve, the position of which is shown by the arrows; *b* is the inlet-pipe projecting above the water-line, conveying the gas into the meter by the bent arm *c*, rising above the water between the convex cover and the inlet-hoods; *d* is a float attached to the inlet-valve, adjusted so that when the water falls below the centre opening, the valve will close, and the gas cease to enter the meter.

Motion is communicated to the train of wheel-work behind the index from a spiral worm *w*, fixed on to the axis of the drum, working into a wheel, the spindle of which passes through the tube *t*, sealed by dipping under the water contained in the case.

The following are the principal dimensions of consumer's meters:—

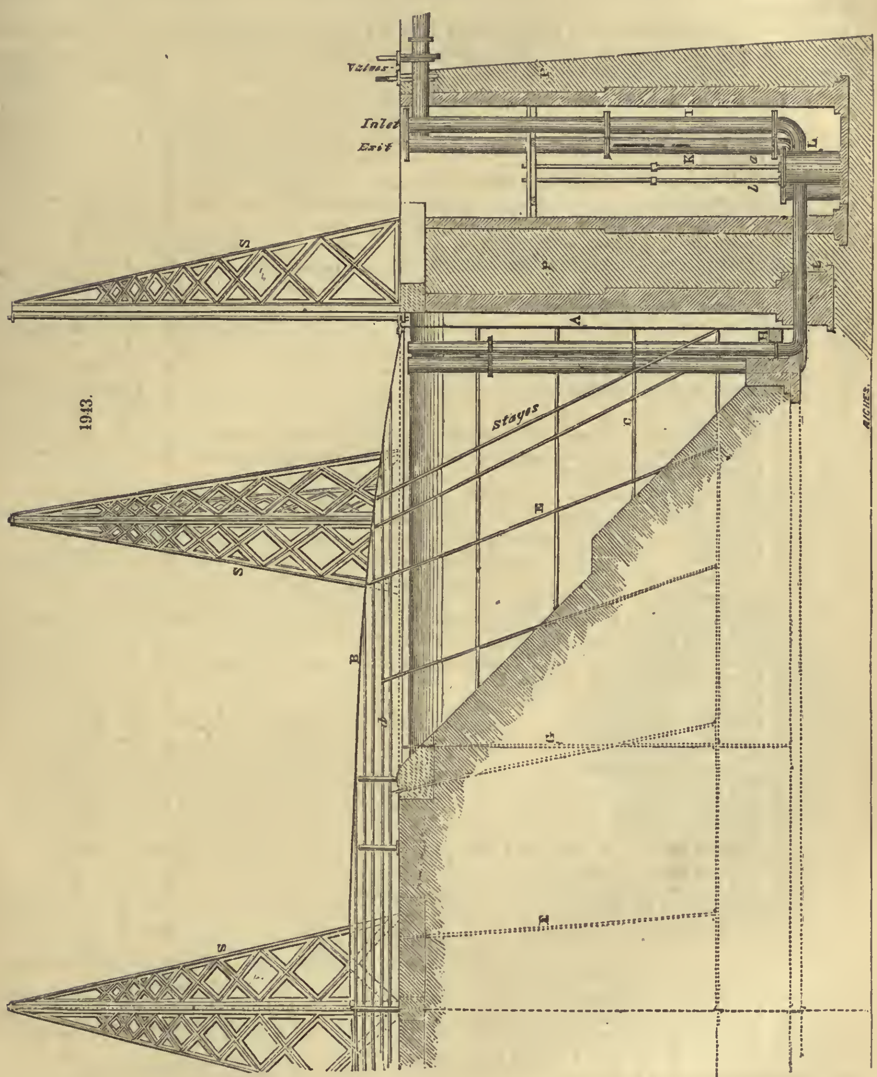
Number of lights	5	10	20	30	50	80	100	150	200	400	800
Diameter of drums . (inches)	$12\frac{1}{4}$	$14\frac{3}{4}$	$17\frac{1}{2}$	$19\frac{1}{2}$	$21\frac{1}{2}$	25	$27\frac{3}{4}$	33	33	44	60
Depth of drums . . . "	5	$6\frac{3}{4}$	$9\frac{1}{8}$	$10\frac{7}{8}$	$11\frac{3}{4}$	$12\frac{3}{4}$	$13\frac{3}{4}$	$20\frac{1}{4}$	$24\frac{3}{4}$	$30\frac{3}{4}$	$40\frac{1}{4}$
Diameter of water circle "	$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{1}{2}$	5	5	$6\frac{1}{2}$	$7\frac{1}{2}$	9	10	15	21
Centre opening . . . "	$1\frac{3}{4}$	2	$2\frac{3}{4}$	3	$3\frac{1}{4}$	4	5	6	7	10	15
Hollow cover projects . "	$\frac{3}{4}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{3}{4}$
Depth of inner hoods . "	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	1	1	$1\frac{1}{2}$	2	3	5
Depth of outlet . . . "	$\frac{3}{4}$	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	4	$5\frac{1}{2}$
Capacity in cubic feet . "	·25	·50	100	1·50	2·00	3·00	4·00	8·00	10·00	20·00	50·00

Gasometers.—The simplest and most general kind, consist of an iron vessel, open at the bottom, and inverted into a tank of water below the surface of the ground, having perfect freedom to rise and fall, and guided by upright rods fixed at several points in the circumference. The diameters and numbers of the vessels will vary according to the magnitude of the works to which they are attached, and the space to be occupied by them. If the works are situated in a town, where ground is too valuable to allow an increased extent, "Telescope Gasometers" are used, which consist of three iron tanks, the one within the other, and working like the slides of a telescope. These require counterpoises, which the simpler form do not, and are more expensive; they work with equal precision, but are not used save in cases of necessity.

Fig. 1943 represents the half section of a simple gasometer, capable of containing 150,000 cubic feet

the diameter being eighty-seven feet six inches, and height twenty-five feet. The sides A A are made of No. 16 iron-plate, (Birmingham wire-gage,) weighing $2\frac{1}{2}$ pounds to the square foot, riveted together; the top B of plate weighing about three pounds to the square foot, or No. 14 gage.

C C, etc., are rings of three-inch T iron, placed five feet asunder, and riveted strongly to the sides; the rivets ought not to be more than three inches apart. The top and sides are secured together by three-inch angle-iron, rolled to fit the curve.



1943.

$d\,d$ are rings of bar-iron, about half an inch thick and three inches deep, fastened to the top by clips, which are riveted; these rings are placed about six feet apart, and strengthened further by diagonal bars, from one to another, breaking-joint.

E are stays formed of wrought-iron pipe, about $1\frac{1}{2}$ inch diameter, fixed in the situations represented, their ends being bolted to the T iron at the sides, and the rings on the top.

G are vertical rods, fixed at their upper and lower ends to the brickwork of the tank, and being passed through eyes fast to the bottom of the side of the gasometer, serve to guide the vessel in its rise: their positions are between the standards S, on which are also guide-rods acting in like manner. The eyes serve as stops to prevent the vessel rising out of the water.

The standards S, eight in number, are each formed of three cast-iron frames, six feet broad at their bases, of the same height as the gasometer, and jointed together in the form of a T on the plan; they are secured to the stone plinth by dovetailed lock-nuts, keyed and leaded.

H is the wooden curb, which ought always to be attached to a gasometer; its use is to regulate the

flow of gas from one gasometer to another. While immersed in the water of the tank it acts as a float, and, to some extent, buoys up the vessel; when the gasometer has risen to its full height, it acts as a weight, being partly *out* of the water, thus causing the gas to flow into another gasometer not yet full, and which, having its curb completely immersed, is under less pressure.

I is the inlet-pipe, of the same diameter as that leading from the retorts, viz. eight inches. Its *mouth* above the water-line should be rather higher than the edge of the tank.

K is the outlet-pipe, twelve inches diameter, entering the gasometer, under the same circumstances as the inlet-pipe.

L are receivers in which the tar or water collects from the mains, being pumped out by a small hand-pump, of which *a* and *b* represent the suction pipes. P, masonry or brickwork.

A gasometer 100 feet diameter and 39 feet high at the sides, containing 300,000 cubic feet, weighs as follows:—

		Tons.	Cwt.	Lbs.
30	Pieces of bottom curb	6	16	30
8	Bags of rivets	0	9	94
60	Plates and rivets for bottom curb	0	1	32
24	Bottom eyes	0	8	24
100	Small sheets, 2 plates each, for side plates	2	8	17
300	Large ditto, 6 plates each, ditto	19	6	7
30	Short pieces of angle-iron bottom curb	0	3	0
24	Vertical stays	10	16	56
60	Pieces of angle-iron top curb	2	13	54
350	Short bracket irons, for crown framing	1	9	45
4	Bags of rivets	0	5	0
1	Centre crown plate	0	9	101
1	Cast-iron cup and ring	0	18	62
1	Centre pipe	0	10	23
6	Bags of rivets	0	9	86
1	Ditto $\frac{3}{4}$-bolts	0	3	90
150	1-inch bolts for top curb	0	5	1
50	Upright rods	2	11	103
50	Ditto, ditto, 6 feet long	1	2	56
50	Ditto, ditto, 3 feet 6 inches long	0	9	7
150	Long braces	3	4	37
196	Crown plates	17	5	71
8	Diagonal stays, at centre pipe	0	2	64
48	Small plates, at bottom and top curb	0	4	4
1	Man-hole, cover, ring, and bolts	0	0	52
130	Small plates for joints and bolts	0	3	15
100	1-inch bolts, and 100 $\frac{3}{4}$ ditto	0	3	64
100	$\frac{5}{8}$-bolts	0	0	60
50	Principal bars for roof	11	17	51
50	Secondary bars	3	16	58
50	Tie-rods for principal	4	17	86
1	Bag of bolts	0	1	17
200	Diagonal stays for roof	1	11	110
72	Cast-iron brackets for vertical stays	0	15	72
24	Timbers for middle, curb, and king-post	1	0	64
48	Tie-rods and bolts for ditto	0	12	24
12	Cast-iron carriages, rollers, and bolts, complete	2	6	56
4	Pigs of lead for ditto	0	3	0
2	Extra man-holes, plates and rings, over 18-inch pipes	0	0	100
	Tons	100	6	101
24	Brackets for guide-rods	2	2	16
24	Lock-nuts for bottom of guide-rods	0	5	16
24	Guide-rods, each 6, 3, 20	9	3	8
12	Sets of tripods, each 8, 13, 3, 1	104	5	12
528	1-inch bolts for ditto	0	18	96
	Tons	116	14	36

A gasometer 36 feet diameter and 12 feet deep contains 12,200 cubic feet, and weighs as follows.—

	Tons.	Cwt.	Lbs.
Ironwork of gasometer, sides of No. 18 and top of No. 17 wire-gage	2	17	57
Wood-curb and diagonals	1	0	97
Stays and bolts	2	5	7
Sundry bolts, man-hole, etc.	0	2	28
Tons	6	5	67
3 Sets of tripods	4	19	28
3 Guide-rods	0	3	21
Tons	5	2	49

It is hardly necessary to observe, that the cost of brick tanks will never be twice alike. If the ground in which the tank of the gasometer represented in the engraving was built, had been less favorable, the thickness of the retaining wall must have been greatly increased, and other expenses incurred, perhaps amounting to one-half more than the cost.

The "working pressure" of a gasometer will depend upon the area of water surface, and the weight of the vessel itself. For example, in the gasometer quoted as 100 feet diameter, the area of water surface is 7854 feet, a stratum of which $5\frac{5}{10}$ths deep will be equal in weight to the gasometer, viz. 100 tons 5 cwts. Its working pressure will therefore be equal to a column of water 5 $\frac{5}{10}$ths of an inch high.

The governor.—The governor is a machine for regulating and equalizing the flow of gas from the gasometers to the street-mains, and is much more perfect in its action than any slide-valve applied for that purpose requiring attendance.

1944.

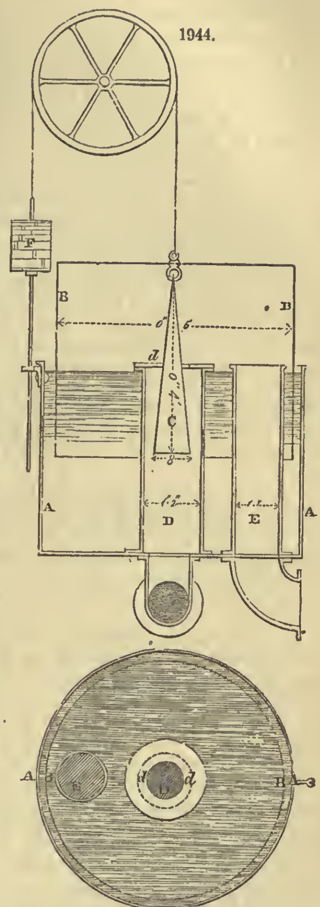


Fig. 1944 is an elevation, in section, and a plan of a governor capable of equalizing the flow of 300,000 cubic feet of gas in twenty-four hours.

A A is a cast-iron tank containing water, five feet four inches diameter, and four feet six inches deep, in which the regulating vessel B B floats.

C is a cone of cast-iron, turned true in the lathe, and suspended by an eye-bolt to the top of the floating vessel.

D is the inlet-pipe, having a plate *d* on the top, furnished with an aperture, bored out to fit the diameter of the cone at the base, and which, if raised to that height, will completely shut off the gas from entering the vessel.

E is the outlet-pipe, its diameter being regulated by the distance to which it has to convey the gas to the equilibrium-cylinder of the street-mains.

The floating vessel B, when immersed in water, of course loses a portion of its weight, equal to that of the water which it displaces; and the density of gas contained in it will vary as the immersion. By making the chain F of a proper weight, it may be made to answer the purpose of a regulator of the pressure. Let it be supposed, for example, that the vessel weighs 1000 lbs., and loses 100 lbs. of that weight when immersed in the water, and that a portion of the chain, equal in length to the height which the vessel rises, shall weigh 50 lbs., and the counterbalance weigh 950 lbs.

	lbs.
Then, when the vessel is immersed, its effective weight is	900
To which must be added the portion of chain now acting, as increasing the weight of the vessel	50
The sum corresponds with the actual weight of the counterbalance	950

	lbs.
Again, let the vessel be elevated out of the water, its actual and effective weight then is	1000
To balance which is opposed the counterpoise	950
And the portion of the chain now removed to the other side of the pulley to counterpoise, and acting with it	50
The sum corresponds with the actual weight of the vessel	1000

The effects of the vessel and counterpoise being thus opposed to each other, the pressure of the gas contained therein is equalized.

By adding or removing the weight of the counterbalance, an increase or decrease of pressure may be effected.

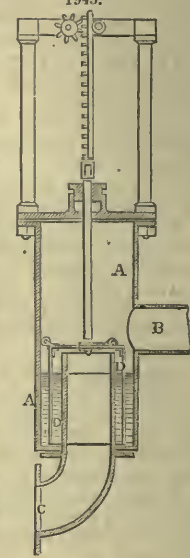
The action of the governor is as follows:—The outlet-pipe is connected with the mains, and the inlet-pipe with the gasometer supplying gas into the machine: it will be evident, that if the density of the gas in the inlet-pipe becomes by any means increased, a greater quantity of gas must pass between the sides of the adjusting cone and the aperture in the plate *d*, the consequence of which will be that the floating vessel will rise, and therefore contract the area of the opening in *d*; and if, on the contrary, the gas in the inlet-pipe decreases in density, the vessel will descend; so that whatever density the gas may at any time assume in the gasometers or mains, its pressure in the floating vessel will remain uniform, and consequently the velocity of the gas passing into the mains will be regular; for when the aperture of the plate *d* would admit more gas than necessary for the supply to the mains, the floating vessel rises and diminishes the area of the inlet-pipe; and when, on the contrary, the inlet does not allow a sufficient quantity of gas to come from the gasometers, the gas passes out of the governor into

the mains, and in so doing the vessel descends, and increases the area of the inlet-pipe, to admit the requisite gas into the mains.

This action is not influenced by any circumstances connected with pressure or velocity, but is constant and uniform, insuring at all times a proper and sufficient discharge.

Pressure indicator.—If a governor be not used, it is advisable to have a *Pressure Indicator* attached to the main or mains that leave the works, to serve as a check upon the conduct of the workmen, whose duty it is to regulate the pressure of gas in them according to the demand at certain hours of the night. It is thus constructed:—A small gasometer about twelve inches diameter is made to move in a tank of water in such a manner that it shall rise or fall according to the pressure in the mains, with which it is connected by a small pipe; a guide-rod, furnished on the top with a pencil, marks the exact amount of pressure upon a sheet of paper coiled round a cylinder. This cylinder is moved round once in twelve hours by a time-piece. It is evident, therefore, that if the paper be divided by horizontal lines corresponding to the rise or fall of the gasometer by every tenth of an inch increase or decrease of pressure; and if it be divided by vertical lines corresponding to the revolutions of the time-piece in twelve hours, it will effect the object required. The gasometer must be formed with an air-vessel inside, so that when it is totally immersed it shall be in exact equilibrium with the external atmosphere; and when risen to its full height it shall have a pressure equal to that required to force the gas through the mains; say the height to which the gasometer rises is equal to ten inches, and the pressure required is three inches; then if the paper be divided into thirty parts by horizontal lines, each division will indicate one-tenth of an inch.

1945.



Pressure-gages, as the name implies, are instruments by which the velocity with which the gas flows into the mains is ascertained. They are made of glass tubes partially filled with colored water, and furnished with graduated scales divided into inches and tenths from a point in the centre of the scale marked zero.

When no gas is passing into the main to which one of these instruments is attached, the columns of water contained in the tubes are in equilibrium with the external air, and stand at 0. When the gas is admitted, the equilibrium is destroyed; the gas depresses one column and raises the other, the total variation being the amount of pressure.

Fig. 1945 shows a section of a water-valve: it is formed of an air-tight cylinder A A, containing a portion of tar or water. B is the inlet-pipe, which communicates with the gasometer; C is the outlet-pipe, which conveys the gas to the mains; D D is an inverted cup, ten inches deep, furnished with a rod passing through a stuffing-box, by which it is raised or lowered. When the cup is in the situation shown in the figure, it is evident that the communication between the outlet and inlet pipes is shut off by the pressure of a column of water ten inches high. When the cup is raised above the mouth of the outlet-pipe by the rack and pinion, a free passage is left for the gas.

This description of valve may be fixed with advantage between the gas-holders and the mains, or between any system of lime-water purifiers.

Mains.—The term main is applied to all cast-iron conduit-pipes that serve to convey gas from the works to the place or district to be lighted, and especially applied to those pipes from which smaller ramifications branch. The diameters of the mains vary from 1½ to 15 or 18 inches, according to the quantity of gas required to be supplied, and the distance it has to flow.

The 1½-inch mains are cast four feet six inches long, the two and three-inch mains about six feet long, and all the other sizes nine feet, with a socket at one end, and a plain bead at the other.

1946. 1947. 1948.

Sockets.—Figs. 1946, 1947, and 1948, represent the sections of sockets of different sized pipes to a scale of 1½ inch to one foot. Fig. 1948 is that of mains from nine to fifteen and eighteen inches diameter. The usual thickness of metal is shown by the hatched lines, and is proved to be sufficient. The *depth* of these sockets is 4½ inches.

Fig. 1947 is a section of the sockets of mains from four to eight inches diameter; their depth four inches.

Fig. 1946 is the thickness of those of a smaller diameter, three inches deep.

The thickness of the main pipes ought to be as follows:—

1½ inch diameter	.... ¼ inch thick.	9 inches diameter	.... ½ inch thick.
2 do. do.	.... ¼ " "	10 do. do.	.... ½ " full.
3 do. do.	.... ¼ " full.	12 do. do.	.... ⅝ " "
4 do. do.	.... ⅜ " "	13 do. do.	.... ⅝ " "
5 do. do.	.... ⅜ " "	14 do. do.	.... ¾ " "
6 do. do.	.... ⅜ " full.	15 do. do.	.... ¾ " "
8 do. do.	.... ½ " "	18 do. do.	.... ⅞ " "

The annular space left between the bead end of one, and socket of the next pipe, should be about half an inch in the large mains, and not less than three-eighths in the small.

Joints.—To make the joints, spun yarn is driven between the pipes to within 2½ inches of the lip of the socket, and a good fitting of the two pipes being effected, melted lead is poured into the remaining cavity, which, when set, is caulked or hammered in with a blunt square-pointed chisel.

In order to guard against the danger of water remaining that enters from the external surface into the pipes, and the deposition of other condensed matter, a reservoir should always be placed at the lowest point, where two or more descending mains meet and form an angle, to receive the water, etc., that may happen to collect at this angular point, an accumulation of which would obstruct the passage of the gas through the mains. These receivers ought to be at least twice the diameter of the mains between which they are interposed, and four times that diameter in depth. These receivers afford the best indication of the sound or leaky state of the system of mains. In all instances where the pipes are perfectly sound, observation has shown that half a mile of gas-mains, three inches in diameter, does not deposit more than a quart of condensed vapor or water in the year; on the other hand, when the mains are leaky, the water of the reservoir requires to be pumped out, particularly in wet weather, as frequently as once a fortnight. The loss of gas by such leakage is much greater than is generally imagined. In order to keep the common air out of the faulty mains, a constant influx of gas is often necessary; this is of course so much gas lost to the economy of the establishment.

Distribution of gas through mains.—The velocities of different gases under the same pressure will be to one another, inversely, as the square roots of their specific gravities; therefore a heavy gas will be discharged through the same opening with a less velocity than that due to a lighter gas. For example, if coal gas of the specific gravity ·420, and with a pressure of five-tenths of an inch, flows through a circular orifice one-fourth of an inch in diameter, at the rate of eighty cubic feet per hour, gas having the specific gravity ·400 will flow through the same opening at the rate of 81·9 per hour, pressure remaining the same. For by inverse proportion,

As $\sqrt{400} = 20{\cdot}000$
Is to 80, the quantity discharged of the heavy gas,
So is $\sqrt{420} = 20{\cdot}493$
To 81·9, the quantity of lighter gas discharged.

The discharges of the same gas through different openings and under the same pressure, are proportional to the areas of the orifices in circular inches, or to the squares of their diameters. Allowing an excess in the larger openings for the difference of the friction, the results of the annexed experiments will agree very nearly with this law.

Diameter of orifice in inches and parts.	Quantities of gas discharged in cubic feet per hour. Pressure = 5-10ths.	
	By experiment.	By calculation.
·25	80	
·50	321	320
·75	723	720
1·00	1287	1280
1·125	1625	1620
1·25	2010	2000
1·50	2885	2880
6·00	46150	46080

To obtain the velocities of the same gas from any other opening, say,

As the square of given opening,
Is to the given quantity discharged,
So is the required opening
To the required quantity discharged.

The quantities of the same gas discharged in equal times by a horizontal pipe under the same pressure and for different lengths, are to one another in the inverse ratio of the square roots of the lengths. Hence, when we know the quantity of gas discharged from a given length of pipe, we may find the quantity discharged by any other length with any pressure, and of gas of any specific gravity.

Example of the foregoing rule.—It is required to find the number of cubic feet that will be discharged from a horizontal pipe six inches diameter and 1760 yards long, the specific gravity of the gas being ·420, and the pressure equal to five-tenths of an inch perpendicular head of water. We know by experiment that 44,280 cubic feet will be discharged by a six-inch pipe 3·46 yards long; therefore, by inverse proportion, say,

As $\sqrt{1760} = 41{\cdot}952$, the required length,
Is to 44,280, the known quantity discharged,
So is $\sqrt{3{\cdot}46} = 1{\cdot}860$, the known length,
To 1963·2, the required quantity discharged.

We therefore find that the loss by friction in a pipe a mile long is 44,116·8, the initial velocity being equal to 46,080 by calculation.

A horizontal main, 16 inches diameter and 1760 yards long, is laid from the works to the equilibrium cylinder: it is required to know how many cubic feet of gas of the specific gravity ·390 will be discharged with a pressure equal to a head of water of 6-10ths of an inch.

We have found by the last example that a six-inch pipe, one mile long, with a pressure of 5-10ths of an inch, will deliver 1963 cubic feet of gas having the specific gravity ·420, in one hour. Then say, as 36, the square of the diameter of the six-inch pipe, is to 1963, the quantity of gas delivered, so is 256, the square of the diameter of the sixteen-inch pipe, to 13,959, the required quantity delivered by a sixteen-inch, one mile long. For the difference of specific gravity, say,

As $\sqrt{{\cdot}390} = {\cdot}197$, the specific gravity of the lighter gas, is to 13,959, the quantity delivered of the specific gravity ·420, so is $\sqrt{{\cdot}420} = {\cdot}204$, the specific gravity of the heavy gas, to 14,455 = the quantity delivered of the specific gravity ·390.

And for the difference of pressure, say,

As $\sqrt{{\cdot}50} = {\cdot}707$, the first pressure, is to 14,455, the quantity discharged through a sixteen-inch pipe by that pressure, so is $\sqrt{{\cdot}60} = {\cdot}774$, the required pressure, to 15,824, the required quantity, of specific gravity ·390 discharged from a sixteen-inch pipe, with a pressure equal to 6-10ths of an inch head of water. The actual quantity discharged is about 16,500 cubic feet.

An accurate experiment was made by Mr. Clegg, at the Pancras Station, on the quantity of gas discharged through a four-inch main, six miles in length, with a pressure of three inches perpendicular head of water. The specific gravity of the gas was not taken until some hours after the experiment, when it was found to be ·398.

A new four-inch main had to be laid for the purpose of supplying parts of the parish of St. Marylebone with gas; after completing a circle of nearly six miles in circumference, it terminated within the distance of a short street from the point at which it left the works. By completing this distance, the two ends of the pipe were brought together on exactly the same level. There were no short bends, and all the services and branches were closed. The pipe measured exactly six miles in length. The leakage was ascertained in the first place by shutting the valve adapted to the returned end, and observing the gasometer; it was found to be thirty-three cubic feet at the end of one hour, and was allowed for. At the commencement of *another* hour the valve was opened and free passage given to the gas, which was allowed to escape: by observing the gasometer at the end of this hour, it was found that 885 cubic feet had been expended; deducting thirty-three cubic feet from this for the leakage, 852 will remain for the actual quantity discharged at the end of six miles. This experiment is valuable to the practical man, both for the unquestionable data it supplies, and for its close approximation to the rules here laid down.

The quantity discharged by calculation is........................... 873 cubic feet
By experiment .... 852 "

Difference.................. 21

TABLES *of the different quantities of coal gas of the specific gravity* ·420, *delivered in one hour, from horizontal pipes of different diameters and lengths, and under different pressures*

QUANTITIES DELIVERED BY A TWO-INCH MAIN IN CUBIC FEET.

Length of pipe in yards.	Pressure in inches and parts.			Perpendicular head of water.		
	0·50	0·75	1·00	1·50	2·00	3·00
10	2896	3558	4135	4923	5792	6950
15	2364	2904	3331	4089	4728	5768
20	2047	2507	2886	3541	4094	4994
25	1830	2241	2580	3165	3660	4465
30	1673	2049	2368	2894	3346	4082
40	1445	1770	2037	2490	2890	3525
50	1294	1585	1824	2238	2588	3157
100	915	1121	1290	1582	1830	2232
150	748	916	1054	1304	1496	1825
200	647	792	912	1119	1294	1578
250	579	709	816	1010	1158	1412
300	522	639	736	903	1044	1273
400	457	559	644	790	914	1115
500	409	500	576	707	818	997

QUANTITIES DELIVERED BY A SIX-INCH MAIN IN CUBIC FEET.

Length of pipe in yards.	Pressure in inches and parts.			Perpendicular head of water.		
	0·50	0·75	1·00	1·50	2·00	3·00
100	8242	10095	11657	14276	16484	20190
150	6730	8242	9517	11657	13460	16484
200	5828	7138	8242	10095	11657	14276
300	4759	5828	6730	8242	9517	11657
440	3929	4813	5557	6806	7858	9626
500	3686	4515	5213	6384	7372	9030
600	3365	4121	4759	5828	6730	8242
700	3115	3816	4406	5396	6230	7632
880	2778	3403	3929	4813	5557	6807
900	2747	3365	3886	4759	5494	6730
1000	2606	3192	3686	4515	5213	6384
1760	1965	2406	2778	3403	3929	4813
2640	1604	1965	2269	2778	3208	3929
3520	1389	1702	1965	2406	2778	3403
5280	1134	1389	1604	1965	2269	2778
7040	982	1149	1389	1702	1965	2298
8800	879	1076	1287	1521	1758	2152
10000	824	1010	1166	1428	1648	2019

QUANTITIES DELIVERED BY A TWELVE-INCH MAIN IN CUBIC FEET.

Length of pipe in yards.	Pressure in inches and parts.			Perpendicular head of water.		
	0·50	0·75	1·00	1·50	2·00	3·00
100	32968	40380	46628	57104	65936	80760
150	26920	32968	38068	46628	53840	65936
200	23312	28552	32968	40380	46628	57104
300	19036	23312	26920	32968	38068	46628
440	15716	19252	22228	27224	31432	38504
500	14744	18060	20848	25536	29488	36120
600	13460	16484	19036	23312	26920	32968
700	12460	15264	17624	21584	24920	30528
880	11112	13612	15716	19252	22228	27224
900	10908	13460	15544	19036	21816	26920
1000	10424	12768	14744	18060	20848	25536
1760	7860	9624	11112	13612	15716	19252
2640	6416	7860	9076	11112	12832	15716
3520	5556	6808	7860	9624	11112	13612
5280	4536	5556	6416	7860	9076	11112
7040	3928	4596	5556	6808	7860	9624
8800	3516	4304	5148	6084	7032	8608
10000	3297	4038	4663	5710	6594	8076

In the foregoing Tables we have considered the mains as *horizontal.*

In mains rising *above* the horizontal line the quantity of gas delivered by them will be greater, and in mains falling *below* that line it will be less. In the first instance, the resistance offered to the flow of gas by the atmospheric pressure will be lessened, and in the latter it will be increased, and will cause a difference in the necessary pressure for the discharge of the gas of one-tenth of an inch head of water for every ten feet rise or fall.

The effect of bends and angles in the main, upon the quantity of gas delivered, is essentially a matter of experiment: they may be considered as so many mechanical obstructions. The results of the following experiments will show, in some measure, what allowance to make for quadrant, semicircular, and right-angle bends. A two-inch pipe thirty feet long, perfectly horizontal and free from obstructions, delivered 2898 cubic feet of gas in one hour, with a pressure of five-tenths of an inch head of water. The same pipe, disconnected in the middle of its length, and returned by a semicircular bend to the point at which it left the gasometer, delivered 2754 cubic feet in the same time, being a difference of nearly one-twentieth in the whole quantity. The semicircular bend was removed and a quadrant bend substituted, making the two fifteen-foot lengths of pipe form a right angle with one another; the quantity delivered was 2834 cubic feet in the hour, a difference of about 1-45th of the first discharge. Again, the pipes were disconnected, and a right-angle bend substituted for the quadrant; the quantity delivered in the hour was 2824, a difference of 1-39th of the first discharge.

Services are wrought-iron or pewter tubes, for the purpose of supplying the interior of houses with gas from the mains; every small tube on to which a burner is fixed, whether for public or private use, is called a *service.* The arrangement of these tubes, and their adaptation to the interior of private dwellings, shops, &c., is a separate branch of business, and "fitters" are almost universally employed, who work independently of the gas companies.

In order that the pipes for conveying the gas from the mains and distributing it through the houses or other buildings to be lighted, may in the first place be neither unnecessarily large or too small, the following rule is given:

One gas-lamp consuming four cubic feet in an hour, if situated forty feet from the main, requires a service not less than a quarter of an inch in the bore.

2 lamps, ...	40 feet from the main, require			a three-eighth service.
3 "	30	"	"	a three-eighth tube.
4 "	40	"	"	a half-inch service.
6 "	50	"	"	a five-eighth service.
10 "	100	"	"	a three-quarter service.
15 "	130	"	"	an inch service.
20 "	150	"	"	a service $1\frac{1}{4}$ in diameter.
25 "	180	"	"	a $1\frac{3}{8}$ service.
30 "	200	"	"	a service $1\frac{1}{2}$ in diameter.

It is desirable that all bends should be circular. No branch ought to proceed from a service of a quarter of an inch in the bore, and no more than two from a three-eighth service. All pipes, before they are fixed, must be proved by condensing air into them by means of a hand-syringe while under water; the leak will be easily detected by the air-bubbles which rise through the water. For conducting the gas from the street-mains into the interior of a house, or any building to be lighted, a wrought-iron pipe of sufficient diameter is tapped into the main, and carried in a straight line to the nearest wall of that building, through which it must pass; and on the inside be furnished with a good stop-cock. If all the fittings rise from the main no siphon is necessary, but if any part of them fall

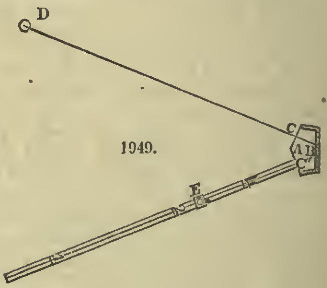
below the main a small receiver must be attached to the lowest point, fitted with a screw-plug at the bottom, so that any moisture may be drawn off. The pipes which convey the gas to the burners must be in as direct a line as possible, to avoid unnecessary expense and obstructions. The union joints used to connect two services together must be of the same diameter as the pipes, and soldered firmly on to them.

The excessive cost and defective construction of fittings have in numerous instances tended more than any thing besides to engender prejudices against gas, and more particularly in private houses.

Gas-fittings ought to be made of the best materials; they should be judiciously arranged, and fixed by skilful workmen. The choice of a situation for the main cock is of importance; it should be placed as near as possible to the inside of the wall through which the gas is admitted from the street-main, and where it will at all times be accessible to the inmates of the house. The key or *spanner* by which it is turned should always be attached, and the nick which indicates whether it is open or shut should be distinctly marked. The cock should be literally a *stop*-cock.

Throughout their various ramifications the pipes should have a slight inclination towards the point where the main cock is fixed, and thence to the street-main; this is to allow the water, which is occasionally deposited in them, to drain off without interrupting the passage of the gas. In fittings which are not thus arranged the water accumulates in some curvature of the pipes, and occasions an oscillation, or, as it is very commonly called, *jumping* of the lights.

The intensity of light is ascertained by an instrument called the Photometer, invented by Count Rumford; it is constructed on the principle that the power of a burning body to illuminate any defined space is directly as the intensity of the light, and inversely as the square of the distance. If two unequal lights shine on the same surface at equal obliquities, and an opake body be interposed between each of them and the illuminated surface, the two shadows must differ in intensity and blackness, for the shadows formed by intercepting the greater light will be illuminated by the lesser light only; and inversely, the other shadow will be illuminated by the greater light—that is, the stronger light will be attended with the deeper shadow: but it is easy, by removing the stronger light to a greater distance, to render the shadow which it produces not deeper than that of the smaller, or of precisely the same intensity; this equalization being effected, the quantity of light emitted by each lamp or candle will be as the square of the distance of the burning body from the illuminated surface. By reference to the diagram, Fig. 1949, the instrument will be rendered perfectly intelligible.



1949.

A is a wooden box, painted black inside, except at the back B, which is painted white, (or a sheet of fine white paper fastened to it may be preferable;) C is the substance intercepting the light of the gas-lamp D, and throwing a shadow on the paper. C is formed of a strip of thin brass, about a quarter of an inch broad, movable round its axis on a pin at the top and bottom, so that its shadow may be adjusted to correspond in breadth to that cast by the lamp; for the candle being nearer, if its intercepting wire were of the same diameter as that of the lamp, the shadow would of course be much broader, and tend to deceive the operator. D is the lamp placed 5 feet from the wire C; E is the candle-socket sliding upon a rod, which is marked according to the number of candles the gas-lamp is equal to.

If, when the candle is placed at 1, the two shadows are equal, the lamp only gives a light equal to one candle; if at 2, the lamp is equal to 4 candles; and if at 4, the lamp is equal to 16 candles.

A simple rule-of-three statement will give the comparative quantities of light, the candle being at any distance. The burner remaining 5 feet from the interposed wire, supposing the candle to be 1 5-10ths of a foot from its wire,

The square of $1{\cdot}5 = 2{\cdot}25$.
The square of $5{\cdot}0 = 25{\cdot}00$.
Then as 2·25, the square of the candle's distance, is to 1·0,
so is 25·00, the square of the lamp's distance, to 11·11, the number of candles the gas-lamp is equal to.

Gas-exhauster.—Much attention has been directed to discover an effectual method of relieving the retorts from the pressure occasioned by the necessary obstructions with which the gas has to contend in the purifying process, and in its subsequent passage to the gas-holder.

The pressure required to surmount these resistances, varies in different establishments according to the method of purification employed, in some cases being equal to a column of water of 36 inches.

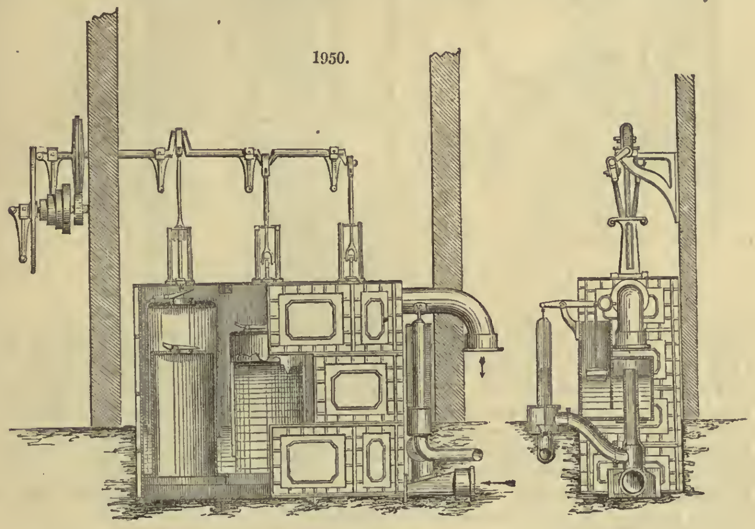
The annexed engraving represents a gas-exhauster designed by Mr. Methven for the Commercial Gas Company's Works, Stepney.

This machine consists of three vertical wrought-iron cylinders, which are made to rise and fall in a tank containing water, by the revolution of a treble crank-shaft with connecting rods and guides.

Each of these cylinders is inverted over a chamber of cast-iron, the interior of which communicates with the hydraulic main. The top of each chamber is provided with a flap-valve, which allows the gas to escape into the movable cylinders, during the ascent of the latter by the action of the crank. The cylinders have valves on the top, similar to those in the cast-iron chambers, which during the descending stroke allow of the discharge of the gas into the upper part of the external cistern. From the cistern a main leads through the purifiers to the gas-holder, and the gas is thus pumped out of the retorts and discharged into the gas-holder, independent of any amount of pressure required to be overcome in its passage.

The velocity of this machine is regulated by the use of conical strap riggers to suit as nearly as possible the amount of gas being generated, but in order to avoid the possibility of the pressure upon the hydraulic main becoming less than that of the surrounding atmosphere, and the gas thereby becoming impoverished by the admixture of atmospheric air, a regulating machine is attached to the exhauster, which, by self-action, maintains that pressure perfectly uniform. The regulator consists of a chamber which communicates alike with the inlet and outlet passages of the exhauster, and which is divided by a valve or conical plug acted upon by a float sustained in water, under the immediate influence of the exhausting power of the machine. The action of the float is communicated to the valve with the smallest amount of friction by a lever and connecting rod with the usual adaptation of a water joint, and the effect is, that when the machine from any cause is reducing the pressure of gas upon the hydraulic main below that of the atmosphere, and thereby causing a partial vacuum in the retorts, the float of the regulator is by the same means depressed, and the communication between the inlet and outlet of the exhauster, thereby opened to a sufficient extent to restore the equilibrium.

1950.



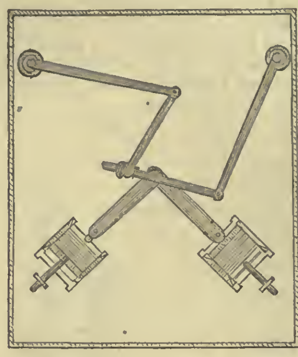
The most perfect equilibrium is maintained between the interior of the hydraulic main and the atmosphere, during the various velocities. The pressure has been even increased to 48 inches of water without any sensible variations in the effect upon the gage indicating the pressure upon the hydraulic main. The highest speed of this machine is calculated to discharge 60,000 cubic feet of gas per hour, at a pressure of 30 inches, and will not then require a driving power greater than that of three horses.

Dry gas-meters.—The ordinary wet gas-meter described, is unexceptionable where fraudulent means are not employed for under-estimating the amount of gas consumed, but its construction admits of great deception being practised by dishonest consumers. If, for instance, the water level in the meter be lowered, more gas will pass through than is registered by the instrument; if the case of the meter be tilted forward to an angle of from 5° to 13°, according to its construction, and a proportion of the water drawn off, so as to expose the outlet of the measuring chamber, the gas will pass through it without affecting the index, and without being registered at all. This is constantly done, and the large amount of gas which is unaccounted for in the calculations kept at the gas-works, and which is frequently attributed to leakage, is no doubt traceable to this nefarious practice. In cold weather the water in the meter is liable to freeze, and the passage of the gas is then completely stopped. The use of a solution of caustic potash or soda has been proposed, which is not so easily affected by frost, to replace the water in the meter, which will also tend to render the gas more pure, should either carbonic acid or sulphuretted hydrogen have escaped the general purifiers. The objections to the use of the wet meter stated above, have given rise to great ingenuity in the construction of a variety of measuring instruments, in which the use of water or any liquid is dispensed with, and in which the gas is measured by the number of times that a certain bulk will fill a chamber capable of undergoing contraction and expansion by the passage of the gas. These alternate contractions and expansions of the chamber set certain valves and simply constructed arms in motion, which, by the aid of a few wheels, can be made to turn the hand of a dial, as in the ordinary wet meter. We will restrict our remarks upon dry meters to one of the most recent inventions, which appear well calculated for affording accurate measurements.

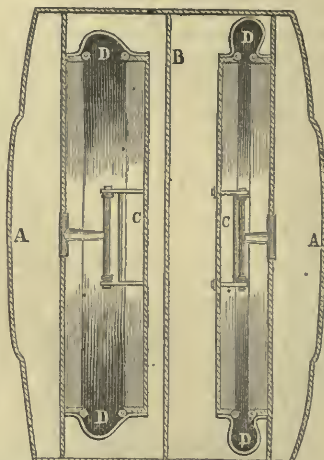
Messrs. Croll and Richards' meter consists of a cylinder or case A A, Fig. 1951, divided by a plate B in the centre into two separate cylindrical compartments, which are closed at the opposite ends by metal disks C C. These metal disks serve the purpose of pistons, and are kept in their places by a kind of universal joint attached to each; the space through which the disks move by the action of the gas, which affords the means of measurement in this meter, is governed by metal arms and rods, shown in the side cut, Fig. 1952, which space, when once adjusted, cannot vary. To avoid the friction attend-

ing a piston working in a cylinder, a band of leather D D is attached, which acts as a hinge, and folds with the motion of the disk; this band is not instrumental in measuring the gas, so that its contraction or expansion would only decrease or increase the capacity of the hinge, the disk being still at liberty to move through the required space only. The leather is also attached in such a manner that it can only bend in one direction, and this renders it much more durable.

1952.



1951.



The machine is comparable to a steam-engine measuring its steam, which it does in all cases by the strokes of the piston. The gas enters the cylinder at the top, from the space occupied by the arms, valves, &c., Fig. 1953, and forces the disks bodily forward through a certain space; the motion communicated by the disks to the arms and rods causes the supply of gas to be cut off, and admits of its escape by another valve; at the same moment the gas is admitted to the other side of the disk, and this is forced to return to its original position, traversing, of course, the same space as before. Each backward and forward motion consequently indicates the passage of a constant quantity of gas, and the same apparatus which admits and shuts off the supply by means of valves is connected with clock-work, and thus the motion of the disk, or the quantity of gas which has passed through the meter can be indicated upon a dial-plate, as in the ordinary wet meter.

Gas-burners.—From the leaden pipes—in the circuit of which the meter is placed, if used at all—the gas enters brass tubes, which project from the wall, and passes to the *burners*, each of which must be furnished with a separate brass stop-cock. Good tight stop-cocks are much more difficult to make for so light a gas, than for liquids. Instead of fixing the carefully ground conical plug into its place by a screw, which occasions either too much friction or an imperfect joint, it is better to use a watch-spring, which, in spite of the wear, keeps the plug always tight. The gas-burners are quite similar to lamp-burners; by the former we are to understand the different mouth-pieces attached to the ends of the tubes for burning the gas. As neither the wick nor the level of the oil has here to be considered, the management of these burners is comparatively simple; but as the amount of fat in candles and lamps required regulation, so here the amount of gas consumed in a given time must bear a proper relation to the current of air from without, *i. e.* the flame must neither smoke, nor must it be too short and blue. Such regulation is partly effected by the cock attached to the burner, and all excess of gas is avoided from the beginning by allowing the gas to issue only from very small apertures. In passing through such apertures, the original velocity of the current of gas is much increased, and the flame thus acquires the proper size and height.

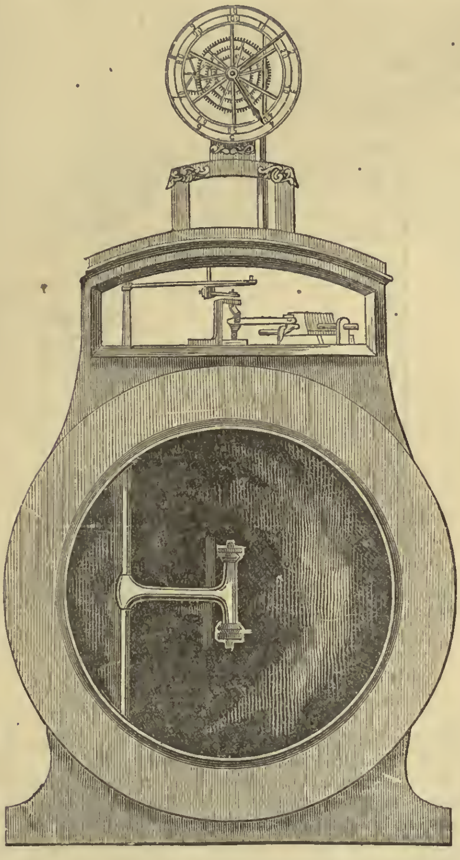
A great variety of gas-burners have been successively brought into public notice, all of which lay claim to the production of an increased intensity of light with a smaller consumption of gas. It is impossible, however, from a mere inspection of the flame produced by these burners, without accurately measuring the amount of gas consumed by each, to arrive at any conclusion as to which form is the most economical or generally desirable. Until impartial comparative experiments have been instituted with all, decided preference cannot be ascribed to any one in particular.

Fig. 1954 is a representation of Whinfield's lucent burner, in which the Liverpool button is applied to an Argand gas-burner, and the peculiar form of chimney causes an external current of air to impinge at a certain angle upon the flame, producing the same effect as the metallic cone in the solar lamp. A basket of wire-gauze is fitted into the crutch of the burner, which moderates the supply of air from below, and prevents the flickering caused by sudden draughts, by fixing the chimney to a circular ring, which screws up or down upon the triangular support. Lowe, in his improvement upon this form of burner, alters the direction of the external current caused by the contraction of the chimney, and by converting the button into a screw, its height can also be altered and the internal current regulated.

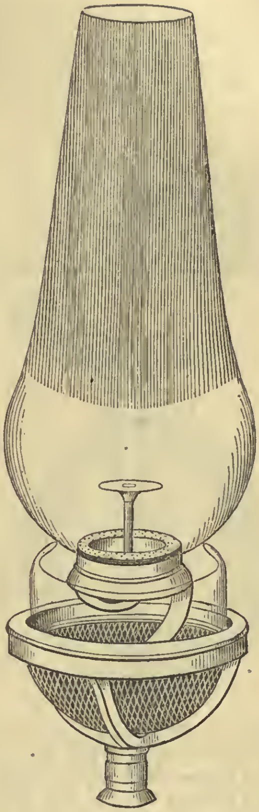
Fig. 1955 shows a form of burner patented by Mr. Leslie, in which the gas is caused to flow through a number of small copper tubes, instead of from the apertures of an Argand burner. The object of this is to effect a more complete combustion of the gas by surrounding each single jet with abundance of air, as it issues from the orifice; and the low form of chimney or combustion chamber diminishes the

velocity of the draught, and adds, consequently, to the illuminating power of the flame. The orifices of the copper tubes become stopped up, either with sulphuret of copper or the ammoniacal oxide, and require to be cleansed with a stiff brush. The only effectual remedy for this objection to the burner, is the use of purer gas.

1953.



1954.

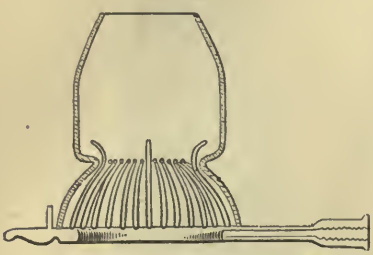


Ventilation of gas-burners.—Serious objections still stand in the way of the introduction of gas-light into private dwellings, unless some means can be adopted for removing the products of combustion. For every cubical foot of gas burnt, rather more than a cubic foot of carbonic acid is produced. A pound of coal gas contains, on an average, 0·3 of hydrogen, and 0·7 of carbon; it produces, when burnt, 2·7 of water, and 2·56 of carbonic acid gas; consumes 4·26 cubic feet of oxygen, which is the quantity contained in 19·3 cubic feet of air. It is thus obvious that the air of a close chamber must soon be vitiated by the combustion of gas, and that the consequences of breathing an atmosphere impregnated with a large proportion of carbonic acid must consequently soon be felt by the inhabitants. The water evolved at the same time, in the state of steam, is found to be seldom free from sulphurous and sulphuric acids, derived from impurities in the gas; and this, condensing upon the furniture, books, goods in shops, &c., very soon damages them in a very perceptible manner. The large quantity of water evolved from the Bude burner in lighthouses, condensing on the glass windows and materially impeding the passage of the light, attracted the attention of Mr. Faraday to the invention of some means for effectually removing the noxious products of combustion. After several more or less successful trials, the method illustrated by Fig. 1956 has been adopted, and exhibits a beautiful adaption of the principle of a descending draught to a lamp-burner: *a* is an ordinary Argand burner, with a common straight chimney *e e*; the glass-holder *c* is, however, so constructed as to sustain not merely the chimney, but an outer cylinder of glass also *f f*, larger and taller than the inner one *e e*; the glass-holder has an aperture *d*, connected by a mouth-piece with a metal tube *i*, which serves as a ventilating flue, and which, after passing horizontally to the centre of the chandelier, ascends to produce draught, and carry off the products of combustion into the chimney or the open air; *d* is the pipe connected with the burner for supplying gas. The outer cylinder *f* is closed at the top by a plate of mica *g*; or still better, by two plates of mica, one resting on the top of the glass, and the other *h* dropping a short way into it. They are connected together by a metal screw and nut, which also keeps them a little apart from each other. The chimney and burner may then be surrounded by a ground-glass globe, which has no opening except at the bottom for the

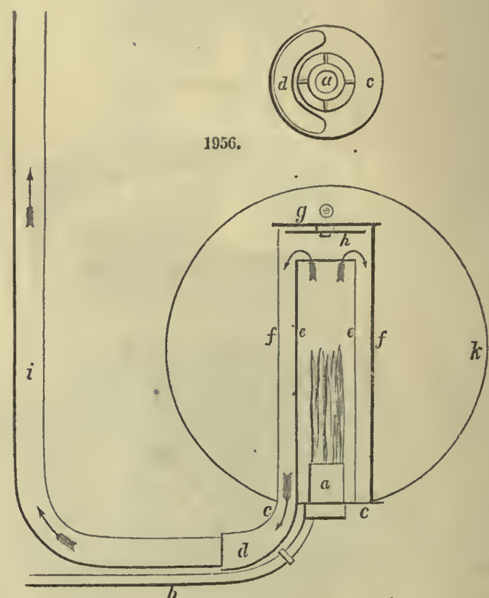
admission of air to the burner. The course of the current of air, carrying with it the products of combustion, is indicated by the direction of the arrows.

It is stated that the intense heat produced by the hot current of air traversing the space between the two glass cylinders, causes the glass to become more or less opaque, and thus obstructs the passage of the light. To avoid this objection, the same principle has been applied in a still more elegant and perfect manner to a ventilating gas-burner, a section of which is represented in Fig. 1957: *b* is the

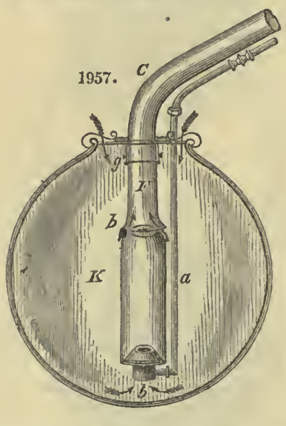
1955.



1956.



1957.



burner, with an ordinary chimney, discharging the products of combustion into the metal tube F; K is a large glass tube, open at the top, in the vicinity of the metal flue F, from which it is suspended. The air for feeding the flame descends in the direction of the arrows, enters the burner at *b*, and is carried off through the flue F C, after having supplied oxygen to the flame and become vitiated. Ventilating burners of this kind not only prevent the diffusion of the products of combustion through the apartments in which they are erected, but with the hot current of gas ascending through the metal tube a large quantity of air from the room is also carried away, and thus a proper circulation established.

GATES, *wrought-iron, for the United States Dry Dock at Brooklyn, New York.*

The danger of accident by fire and decay, and the increasing difficulty of procuring timber, especially of large dimensions or peculiar shapes, has directed the attention of engineers to the substitution of iron for wood in structures designed for permanence. European engineers have been long forced to make this substitution, by the increasing cost of timber.

The ingenuity and skill of artisans have led to some very beautiful designs and applications of iron, producing great strength with small weight and dimensions. The substitution of iron for wood has been heretofore chiefly confined to the construction of vessels and bridges. Sufficient experience has demonstrated the great superiority of iron over wooden vessels, and as soon as the prejudices of the old constructors are overcome it will doubtless be used exclusively.

In America timber can be obtained at a moderate cost, unless it be of unusual dimensions or shapes, and a general substitution of iron will be more distant. The difficulty of procuring the immense timbers required for the construction of the folding gates of the graving dock at New York, led to an examination of the question of substituting iron for wood.

There have been no works of this kind constructed in America; and even in England and France most of the recently built docks have been provided with gates of wood. A few iron gates of large size have been constructed; among them are those for the new graving and wet docks at Woolwich, Sheerness, Shinburness, Bristol, Dundee, and Montrose, and for the locks on the Caledonian and Elsmere canals at an earlier date, and also for the docks at Sevastapol on the Black Sea.

The mode of constructing these gates has not been published, except in the case of the docks at Montrose, and the gates of the locks of the Caledonian canal. The general plan which has been adopted has been to construct a frame of cast-iron, and cover it with a sheathing of wooden planks; some of those recently constructed are covered with a sheathing of boiler-plate.

The low temperature of the atmosphere in this climate renders the use of cast-iron dangerous where

it is subject to violent concussions; and to avoid this difficulty Mr. McAlpine (the engineer who designed these gates) proposed the adoption of wrought instead of cast iron for the frames of the gates.

The successful introduction of these plates of wrought-iron in the construction of the tubular bridges over the Menai Straits, has given a direction to the use of this kind of iron which will produce important changes in the designs of such structures.

A beautiful application of the same description of iron has been made in the design for the gates of the graving dock at New York.

It is believed that no experiments have hitherto been made, at least none have been published, on the strength of iron thus applied. Some of the best practical engineers in the United States have expressed doubts as to the strength of the horizontal ribs of the gates as arranged on the annexed plan. To satisfy these doubts, a trial-bar was modelled after the form proposed, and full size, and subjected to pressure. The result of this experiment has proved that the strength of a bar thus formed has been under instead of over rated.

The following tables of the deflection of the bar under various weights possess great interest.

The bar was set up, supported at its extremities, and loaded by weight suspended from the centre, provision was made against the lateral extension of the bar by placing it between solid abutments of masonry, which happened to be convenient for the purpose; care was also taken to preserve it in a truly vertical position. The whole arrangement is shown in the annexed sketch.

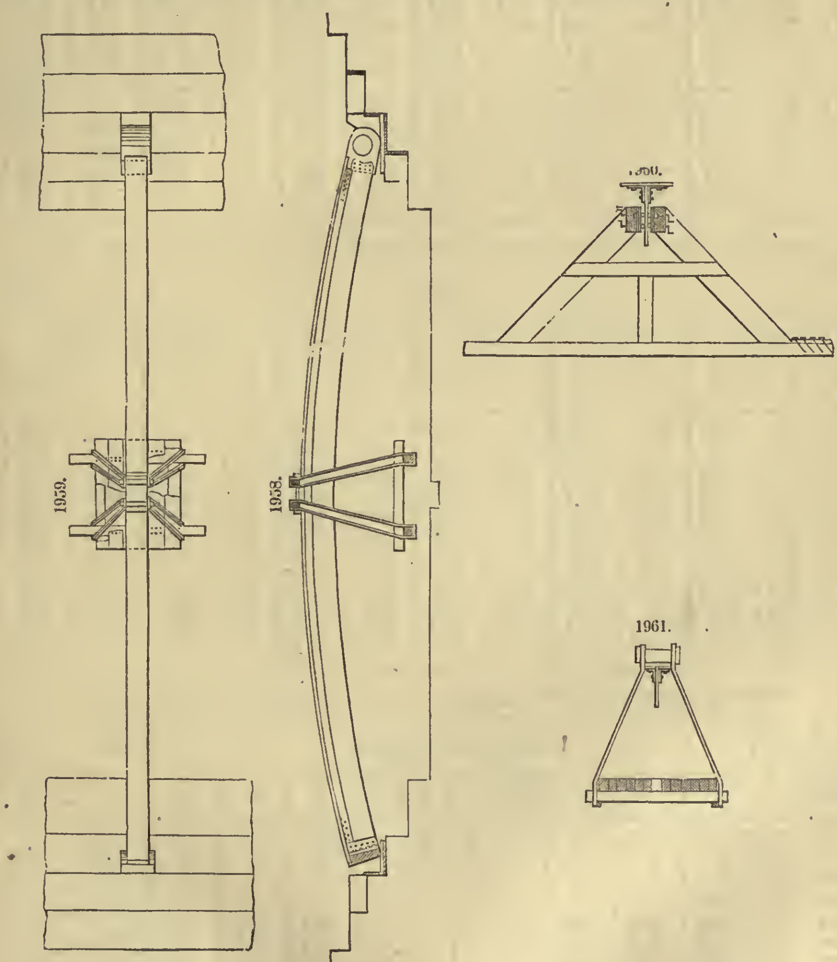


Fig. 1958, elevation of the apparatus used in testing the strength of the wrought-iron bar intended for the folding gates of the United States Dry Dock, Brooklyn Navy Yard.

Fig. 1959, plan of the same.

Fig. 1960, cross section of the frames for preserving the bar upright: Fig. 1961, scale.

Levels taken at each loading on different parts of the bar, as well as the weights applied at each loading, are given in the tables. The weights are given in pounds, and the deflections in decimals of a foot.

The bar was thirty-seven feet long, twenty-two inches wide, and three-fourths of an inch thick, and made of three plates, for the length, secured by splicing plates riveted.

The point marked No. 5 in the table was in the centre of the bar, and the other points equally distant from each other.

TABLE No. 1.

No. of mark on boards.	TRIALS.											
	No. 1. 9,798 lbs.		No. 2. 16,821 lbs.		No. 3. 24,697 lbs.		No. 4. 32,883 lbs.		No. 5. 39,710 lbs.		No. 6. 55,132 lbs.	
	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.
0	·000	·000	·005	·005	·009	·004	·005	·001	·008	·009	·012	·003
1	·000	·000	·003	·003	·005	·002	·004	·002	·003	·001	·001	·000
2	·002	·002	·005	·007	·002	·005	·010	·015	·004	·011	·011	·022
3	·001	·001	·004	·005	·007	·012	·005	·017	·007	·024	·007	·031
4	·003	·003	·009	·012	·008	·020	·004	·024	·010	·034	·014	·048
5	·025	·025	·007	·032	·008	·040	·006	·046	·022	·068	·005	·073
6	·001	·001	·010	·009	·008	·017	·003	·020	·010	·030	·010	·040
7	·004	·004	·008	·012	·004	·016	·008	·024	·001	·025	·016	·041
8	·002	·002	·005	·003	·005	·008	·002	·010	·001	·009	·002	·011
9	·001	·001	·003	·002	·001	·003	·000	·003	·000	·003	·002	·005
10	·000	·000	·003	·003	·003	·006	·008	·002	·008	·006	·003	·003

The bar was then left, loaded with 55,132 pounds, for 20½ hours, at which time the loading was resumed.

TRIALS.

No. of mark on bar.	No. 7. 55,132 lbs.		No. 8. 61,786 lbs.		No. 9. 67,788 lbs.		No. 10. 76,143 lbs.		No. 11. 84,620 lbs.		No. 12. 92,609 lbs.	
0	·006	·003	·000	·003	·000	·003	·002	·005	·002	·003	·000	·003
1	·000	·001	·002	·003	·001	·004	·002	·002	·002	·004	·000	·004
2	·005	·007	·004	·025	·005	·026	·003	·029	·003	·032	·019	·051
3	·001	·030	·005	·035	·005	·040	·012	·042	·011	·053	·044	·097
4	·001	·049	·011	·060	·012	·072	·007	·079	·010	·089	·080	·169
5	·003	·070	·008	·178	·011	·089	·007	·076	·012	·108	·057	·165
6	·000	·040	·005	·045	·005	·050	·005	·055	·013	·068	·051	·119
7	·008	·033	·008	·041	·004	·045	·008	·053	·008	·061	·039	·100
8	·002	·013	·001	·014	·002	·016	·001	·015	·004	·019	·019	·039
9	·004	·001	·001	·000	·003	·003	·001	·004	·000	·004	·004	·008
10	·001	·004	·002	·002	·001	·003	·001	·004	·001	·003	·000	·003

Table showing the amount of elongation in the bar during the first experiments.

Weight on the bar in pounds.	No. of Experiments.	Different points on the bar.										Observations.
		a.	1	2	3	4	5	6	7	8	C.	
		in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	
	0	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0	*a* and C were points immediately over the plumb face of altar No. 9;—more reliance may be placed on their accuracy than on that of the others.
9,798	1	...	...	...	...	...	...	...	...	...	...	
32,883	4	·005	...								·005	
39,710	5	·005	·003	·001					·001	·003	·005	
55,132	6	·010	·008	·005	·003			·005	·007	·005	·010	
61,786	8	·010	·008	·005	·003			·005	·007	·008	·010	
69,788	9	·015									·010	
76,143	10	·016									·010	
84,620	11	·016									·013	
92,609	12											

NOTE.—In consequence of an imperfection in the arrangement which was made for securing the beam in a vertical position, at the twelfth loading, it lurched to one side, and prevented a continuance of the experiment.

The bar was repaired, and the following experiments were made without abutments, which allowed the ends to move horizontally; it was loaded as stated in the first set of experiments.

TABLE No. 2.

No. of mark on bar.	No. 1. 11,771 lbs.		No. 2. 20,354 lbs.		No. 3. 31,495 lbs.		No. 4. 33,673 lbs.		No. 5. 33,673 lbs. Between 4 and 5 an interval of 15 hours.		No. 6. 35,961 lbs.	
	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.
0	·001	·001	·001	·002	·001	·003						
1	·002	·002	·001	·003	·001	·004						
2	·013	·013	·014	·027	·018	·045						
3	·026	·026	·021	·047	·030	·077						
4	·035	·035	·028	·063	·038	·101						
5	·035	·035	·035	·070	·046	·116	·010	·126	·005	·131	·007	138
6	·031	·031	·031	·062	·045	·107						
7	·029	·029	·023	·052	·032	·084						
8	·016	·016	·012	·028	·020	·048						
9	·005	·005	·008	·013	·003	·016						
10	·000	·000	·000	·000	001	·001						

No. of mark on bar.	No. 7. 38,033 lbs.		No. 8. 40,131 lbs.		No. 9. 41,973 lbs.		No. 10. 44,456 lbs.		No. 11. 46,074 lbs.		No. 12. 48,179 lbs.	
	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.
0								·005				·006
1								·010				·010
2								·074				·085
3								·130				·154
4								·175				·203
5	·014	·152	·008	·160	·017	·177	·023	·200	·008	·208	·020	·228
6								·183				·209
7								·143				·166
8								·085				·098
9								·028				·033
10								·004	·000	·004	·000	·004

The bar was then left, loaded with 48,179 lbs., for 20 hours, at which time the loading was resumed

No. of mark on bar.	No. 13. 48,179 lbs.		No. 14. 52,209 lbs.		No. 15. 56,694 lbs. Between 15 and 16 an interval of 20 minutes.		No. 16. 56,694 lbs. Between 15 and 16 an interval of 20 minutes.		No. 17. 58,894 lbs.		No. 18. 58,894 lbs. Between 17 and 18 an interval of 20 minutes.	
	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.
0	·002	·008	·001	·009	·001	·010	·000	·010	·000	·010	·000	·010
1	·003	·013	·000	·013	·000	·013	·000	·013	·000	·013	·000	·013
2	·008	·093	·002	·095	·016	·111	·010	·121	·007	·128	·006	·134
3	·013	·167	·004	·171	·036	·207	·018	·225	·016	·241	·012	·253
4	·015	·218	·008	·226	·043	·269	·026	·295	·019	·314	·015	·329
5	·018	·246	·015	·261	·047	·308	·026	·334	·025	·359	·015	·379
6	·017	·226	·004	·230	·050	·280	·027	·307	·020	·327	·020	·341
7	·013	·179	·004	·183	·036	·219	·020	·239	·016	·255	·014	·267
8	·008	·106	·003	·109	·029	·129	·014	·143	·009	·152	·009	·161
9	·003	·036	·002	·038	·009	·047	·000	·047	·004	·051	·001	·052
10	·000	·004	·000	·004	·000	·004	·001	·005	·000	·005	·000	·005

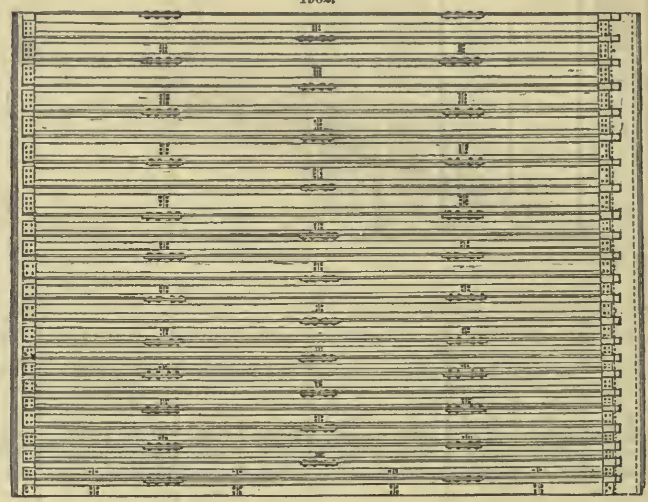
1966.

1964.

1963½.

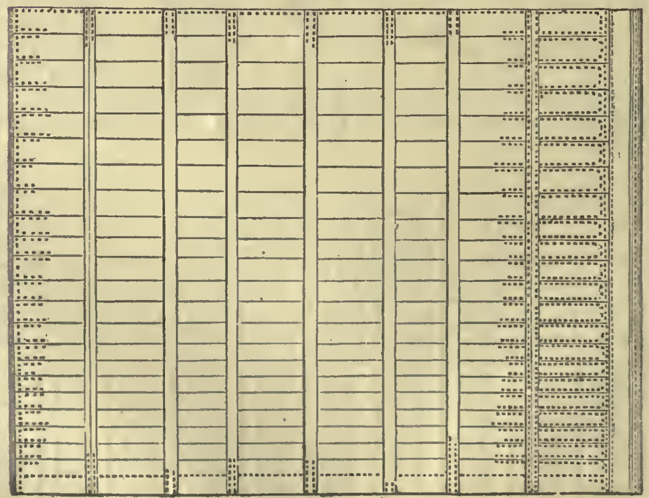
1963.

1962.



1965.

1967.



No. of mark on bar.	No. 19. 60,904 lbs.		No. 20. 63,104 lbs.		No. 21. 65,284 lbs.		No. 22. 65,284 lbs.		No. 23. 65,284 lbs. Between 22 and 23 an interval of 2 hours 50 min.		No. 24. 65,284 lbs. Between 23 and 24 an interval of 17 hours.	
	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.	Deflection.	Total Deflection.
0	·000	·010	·000	·010	·000	·010	·001	·011	·000	·012	·001	·015
1	·000	·013	·000	·013	·000	·013	·001	·014	·000	·014	·003	·017
2	·008	·142	·023	·165	·015	·180	·011	·191	·004	·195	·005	·200
3	·014	·267	·048	·315	·013	·328	·038	·366	·007	·373	·006	·379
4	·022	·351	·064	·415	·022	·437	·049	·486	·007	·493	·010	·503
5	·026	·405	·076	·481	·034	·515	·054	·569	·012	·581	·010	·591
6	·022	·363	·077	·440	·028	·468	·039	·507	·013	·520	·007	·527
7	·016	·283	·059	·342	·028	·370	·024	·394	·007	·401	·008	·409
8	·010	·171	·029	·200	·019	·219	·012	·231	·005	·236	·005	·241
9	·003	·055	·013	·068	·003	·071	·003	·074	·001	·075	·006	·081
10	·000	·005	·000	·005	·000	·005	·000	·005	·000	·005	·000	·005

These experiments having demonstrated that the bars as arranged were of sufficient strength, the construction of the gates was commenced.

Fig. 1962 shows an elevation of the back side of the gate.

Figs. 1963 and 1963½ are vertical and horizontal sections of the mitre post.

Figs. 1964 and 1965 are the same sections of the quoin post.

Fig. 1966 is a plan of the horizontal rib, and a horizontal section of the gates.

Fig. 1967 is an elevation of the front of the gate.

In the article "Dry Dock," at page 401, a full description and specifications of these gates are given, to which the reader is referred.

There being nothing peculiar in the capstans and sluice-gates and other fixtures, they have been omitted in the drawings.

No. of mark on bar.	No. 25. 67,314 lbs.		No. 26. 71,304 lbs.		No. 27 75,299 lbs.	
	Deflection.	Total deflection.		Total deflection.		Total Deflection.
0	·002	·015				·010
1	·002	·019				
2	·005	·205				·423
3	·007	·386				·844
						ft. in.
4	·007	·512		·820		1·152
5	·004	·595				1·450
6	·003	·530		·860		1·272
7	·001	·410				·953
8	·008	·249				·514
9	·003	·084				·169
10	·000	·005				·000

The levels of experiment No. 57 were taken after the bar broke.

GATES, CANAL. See Locks of Canals.

GATES, FLOATING. *Specifications for constructing the wrought-iron floating gate, or caisson, for the United States Dry Dock, at the Brooklyn Navy Yard, represented in plan, section, and elevation in* Figs. 1968, 1969, 1970.*

Dimensions.—The vessel is to be 50 feet long on the keel and 69 feet on the deck. The width in the centre is to be 4 feet on the bottom, and curved to 16 feet at 6 feet above the bottom, and to continue this width to the top.

The width at the end is to be two feet.

The whole height is to be 31 feet.

The sides are to be curved on a radius of 83 feet 7 inches at the top, and diminished so as to preserve the width at the stems (2 feet) and in the centre (16 feet) for the upper section of 24 feet.

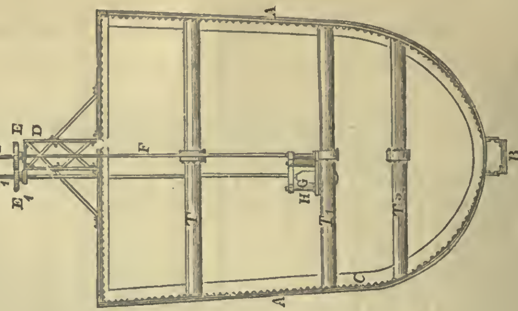
The ends or stems are to be built to conform to the shape of the masonry of the dock. The bottom or keel is to be 50 feet long, straight; the stem is to be curved on a radius of 3 feet 10 inches for 2½ feet in height, and then on a curve of 56½ feet radius for 19⅝ feet in height, and then carried up on a level to the top, 9 feet in height, making the whole height (including the keel) 31 feet.

Ribs.—There are to be 26 ribs on each side of the gate. The 14 centre ribs are to be 24 inches apart, 4 to be 25, 4 to be 26, and 4 to be 27 inches apart; each set of ribs are to be formed of 4 plates exclusive of the bulwarks. The two bottom plates from the opposite side are to lap past each other 3 feet over the keel, the lips being turned opposite ways to allow them to be riveted together where they lap.

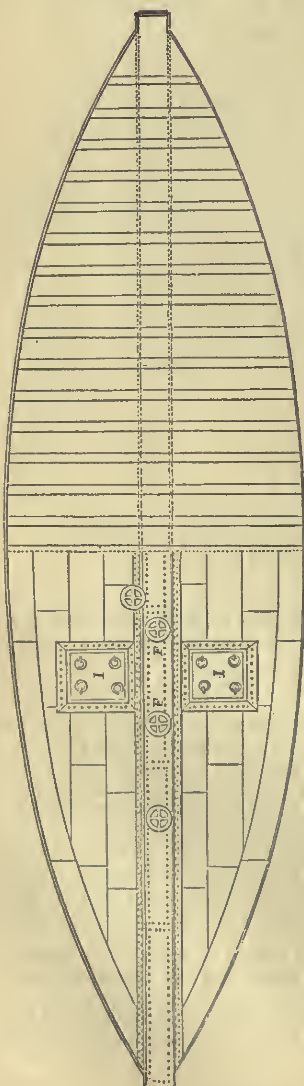
The two bottom plates are to be each 20 feet long, and are to be formed of angle iron, 5 inches on each angle and ¾ inches thick, with rivets ⅝ inches diameter, and 4 inches apart, or rectangular plates of iron 6 by 1 inches, secured by angle iron.

The two side plates are to be each 20 feet long, and to lap past the bottom plates 9 feet, and to be riveted to them; the rivets are to be ½ inch diameter, and 6 inches apart. They are to be formed of angle iron, 4 inches on each angle and ½ inch thick.

* A general description of the caisson or floating gate is given in the article "Dry Dock," p. 402.

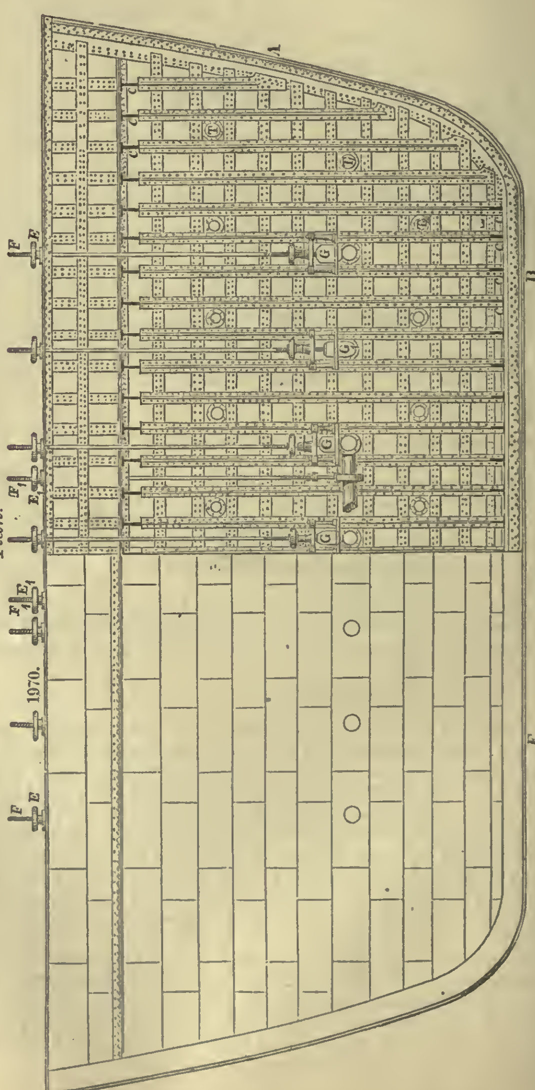


1969.



1968.

Plan.



1970.

The bulwarks are to be formed of plates 7 feet long, and to lap on and be riveted to the side plates they are to be formed of angle iron $2\frac{1}{2}$ by 3 inches, and $\frac{3}{8}$ inch thick.

Sheathing.—The bottom plates are to be bent to form the sides of the keel; they are to be 6 feet long, 2 feet wide, and $\frac{5}{8}$ inch thick. The vertical joints are to be butted; the plates are to be riveted to the angle iron running lengthwise of the keel, with $\frac{5}{8}$ inch rivets $2\frac{1}{2}$ inches apart; they are also to be riveted to the angle iron of the ribs in the same manner.

The horizontal joints are to be butted on a line, and the plates to be riveted to a piece of iron on the inside, between the ribs, 4 by $\frac{5}{8}$ inches; the rivets to be as before described.

The rivets on the bottom and sides of the keel and stem, and the bottom of the vessel, are to be countersunk.

The sheathing plates, to a vertical height of 6 feet 10 inches, will be made of the same sized plates, and secured and riveted in the same manner.

The next two courses above are to be made of $\frac{1}{2}$ inch plates; the next four courses above of $\frac{3}{8}$ inch plates; the next three courses of $\frac{1}{4}$ inch, and the bulwarks of 3-16th inch plates, all secured and riveted in the manner above described.

The rivets through the $\frac{5}{8}$ and $\frac{1}{2}$ inch plates will be $\frac{5}{8}$ inches diameter, and $2\frac{1}{2}$ inches apart; through the $\frac{3}{8}$ and $\frac{1}{4}$ inch plates they will be 9-16th inches diameter, and $2\frac{1}{2}$ inches apart; through the 3-16th inch plates they will be $\frac{3}{8}$ inches diameter. The lapping plates on the inside of the horizontal joints will be made of the same thickness as the sheathing plates. The bulwarks will be braced with light wrought-iron knees, and sealed up on the inside with light sheet-iron.

The keel and stems.—The keel and stems are to be formed of a single plate of iron for the keel, and each stem forged and welded together. The plates are to be 2 feet wide, and $\frac{5}{8}$ inch thick.

The sides of the keel are to be made by bending the bottom sheathing plates, and of the stems, by bending the side sheathing.

The bottom plates and the sheathing are to be connected by angle iron, 4 inches on each flange, and $\frac{3}{4}$ inch thick, to which both plates are to be riveted. The rivets are to be $\frac{3}{4}$ inch diameter, $2\frac{1}{2}$ inches apart.

The stiffening plates in the keel will be 3 feet long on the top, 15 inches deep, and 1 inch thick; plates of cast-iron, transversely and longitudinally, are also put in.

The part which projects into the keel will be cut to the interior shape, cutting out the bottom corners for the angle iron, and the shoulders to fit against the bottom sheathing plates.

The stiffening plates will be placed between the plates of each rib, and will be riveted or bolted through both plates, where they lap past each other.

The nine courses of horizontal stiffening plates in the stems are made of cast-iron, conforming to the curve of the sides of the vessel on the outside edge, and fitted to the shape of the interior of the stem. They are to be placed at each horizontal joint of the sheathing, and take the place of the butting strips. Plates of angle iron 3 inches wide on each flange, and $\frac{1}{2}$ inch thick, will be riveted to the sheathing plates, and bolted to the stiffening plates.

Deck.—The angle iron is to be 4 by 2 inches, $\frac{1}{2}$ an inch thick. The covering is to be formed of sheets about 6 feet long, 2 feet wide, 3-16th inch thick, made of scratched iron. Rivets to be $\frac{3}{8}$ inch diameter, and 2 inches apart.

The combing of the hatches will be made of cast-iron, bolted to the angle iron.

Suitable ring-bolts will be put in the deck, and on each quarter outside of the vessel.

Tube braces will all be 14 inches diameter, and made of $\frac{1}{2}$ inch wrought, or 1 inch cast iron; the flanges of the tubes are to be $2\frac{1}{2}$ inches wide on each end, and bolted to the sheathing.

The cast-iron chambers will be cast in halves, and planed and fitted together, and riveted through the chamber and flanges of the tube, and secured with tap bolts on the top.

The valves will be of cast-iron, planed and fitted; the seats will also be planed and fitted closely.

There will be four branch pipes discharging into the interior of the vessel, by means of similar valves.

The valves will be raised by a stem of $1\frac{1}{2}$ inch round iron, guided by a frame, and operated by a hand-wheel and screw on the level of the deck.

There will be a steam-engine with a cylinder of 6 inches diameter and 18 inches stroke, and a suitable locomotive boiler set under the deck, and two double acting force-pumps 15 inches diameter, (the pumps are also to be arranged to be worked by hand.) The whole is to be made portable.

A flight of iron steps is to be put in at the stem at each end, and extend from the deck to the bottom of the vessel.

The keel will be suspended from and braced to the sides of the vessel, to meet the different strains to which it will be subjected when floating, and when aground in peace. This bracing is made by a trussing of hollow cast-iron pipes, 5 inches diameter, through which are passed suspension rods of wrought-iron, $2\frac{1}{2}$ inches diameter.

General remarks.—All of the joints exposed to the water shall be chipped, and calked so as to be water-tight.

All of the iron and other materials used shall be of the best quality, and shall be bent and forged to the required shape, to conform to the plans, and shall be neatly and accurately fitted.

The riveting shall be done when hot, and the rivets made to fill the hole completely.

The whole surface, both outside and inside, shall be painted with two coats of red lead and oil, and a third coat of such other color as may be directed.

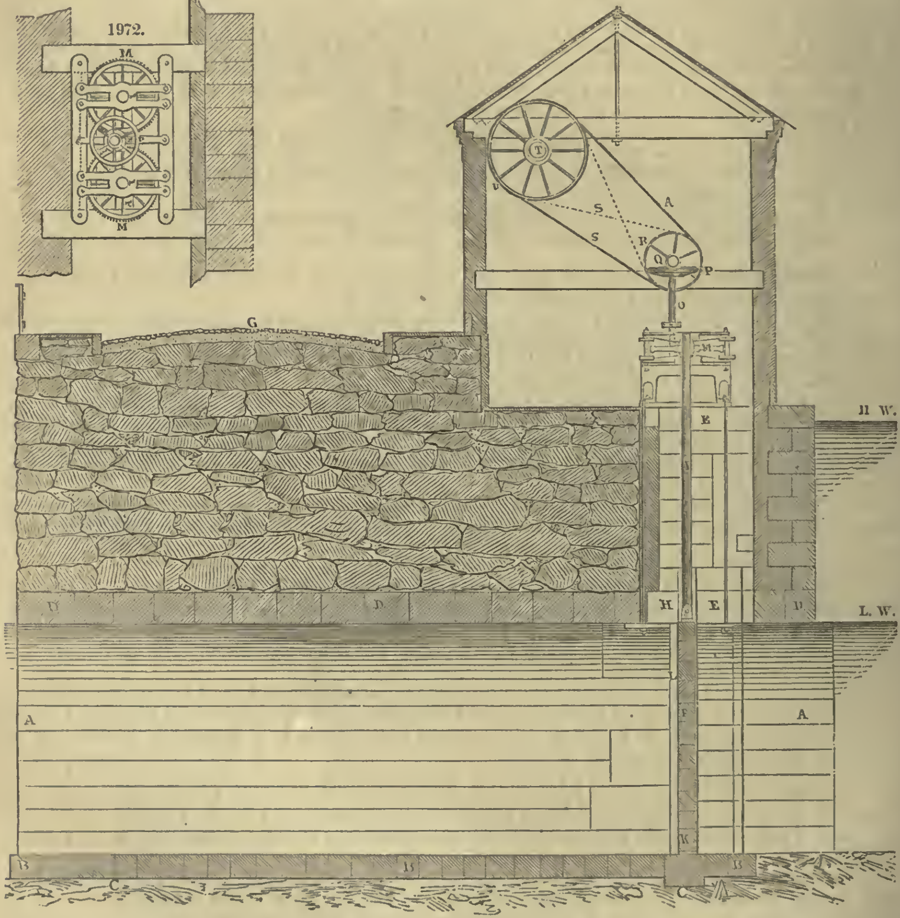
GATES, GUARD. One of the most complete examples to be found is at Lowell, Massachusetts, at the head of the Northern Canal, the principal feeding canal to the large manufacturing establishments of that city. It was constructed by James B. Francis, Esq., Agent of the Locks and Canals Company. The average width of the canal is 100 feet, the depth of the water 15 feet; the sides being nearly perpendicular. The guard gates are placed at its entrance from the Merrimack river, for the purpose of reguating the quantity of water to be admitted, and for protecting the canal and a considerable part of the

city from freshets, which sometimes raise the level of the water in the river 10 to 13 feet above its ordinary height. The entrance to the canal being nearly in the direct line of the stream, it was necessary that the guard gates and masonry should be of great solidity, to withstand the violent action of the ice in the spring freshets; as the river sometimes breaks up suddenly when the ice is from eighteen inches to two feet thick, and not sensibly weakened by previous warm weather.

Figs. 1971 and 1972. The water is admitted to the canal through ten openings, each eight feet wide and fifteen feet deep in the clear. These openings are separated by piers of hammered granite A A, two feet thick, fifteen feet high, and a little over fifty feet long. These piers rest on a granite paving B B B, laid on the rock C C of hard mica slate. The openings are covered with granite lintels D D D, about two feet thick, resting on the piers; wells E E being left for the gates F. Above the lintels the masonry is carried up under the gate-house to the height of twelve feet, and below the gate-house, six feet higher, for the passage of the road G leading to the Pawtucket bridge across the river.

1971.

1972.



The gates F are made of white-oak timber, one foot thick, laid one above the other, and connected together with four bolts, two inches in diameter, passing through the feet of the castings H, to which the screws I are attached, and passing down through the middle of the gate to a cast-iron plate K, forming the bottom of the gate. The ends of the gate project into grooves at each end, and are faced with plates of cast-iron 7 inches wide and 1½ inch thick. These plates slide on the castings L built into the masonry; the sliding surfaces being planed so that they make a joint nearly water-tight. The gates are raised and lowered by means of two screws I I, about 17 feet long and 5 inches diameter, with threads of one inch pitch. These screws pass through the hubs of the pair of geers M M, which are cut into female screws. The pair of geers are driven by one pinion N placed at the bottom of the upright shaft O, on the top of which is a bevel geer P, driven by another pinion Q placed on a horizontal shaft driven by pulleys R and leather bands or belts S S, three inches wide. There are two sets of pulleys and belts to each gate, one to raise the gate, the other to lower it. The proportions of the geering are such that the belt travels 1800 times faster than the gate. The belts are all driven

by the shaft T carrying the pulleys U. This shaft is driven by a water wheel of fifty horse power, by which means the whole of the gates can be lifted at one time, under almost any circumstances, in fifteen minutes.

GAUGE OR GAGE. A measure of capacity or pressure. Of steam gages to denote the pressure on boilers, the most used at present is the Bourdon Steam Gage, generally called from the name of the party introducing it in this country, the Ashcroft Gage.* The principle of its construction is as follows. If a thin metallic tube be nearly flattened, and afterward coiled, the effect of an inward pressure is to force it toward its original shape—the first effect produced being that of tension toward elongation, whether the flattened tube be coiled or twisted; and a contrary effect is produced by unresisted exterior pressure. In shaping it, a certain degree of elasticity having been given to the metal, as long as it is not absolutely forced beyond a given point of its acquired shape, it will act as a spring to the greatest perfection, and work from or back to its newly acquired shape, as the pressure upon it may be applied. Thus, a simple piece of well-made metal tube is first partially flattened in all its length, and coiled nearly to a circle. One end of it is stopped up, while the other end is left open, to receive the pressure of steam or water. To the end that is stopped a hand is fixed, which is so placed as to show the variations in the position of the tube upon a dial marking the degrees of pressure. A vacuum gage is made of the same simple piece of mechanism, reversing the application of pressure, and, consequently, the effect upon the tube. For instance, as exhaustion takes place in the tube, so does its power of resisting the pressure of the surrounding atmosphere which acts upon it vary, and it consequently again coils under that pressure in regular ratio with the variation of it, and is made to indicate the degree of vacuum in the condensers of an engine.

1973.

1974.

Fig. 1973 represents the dial and index of one of these gauges; fig. 1974 the gage with the dial removed. A is the thin curved tube, into the end of which the steam is admitted whilst the opposite closed end is attached to one extremity of a segment which geers into a pinion on the index shaft. These gauges are tested by a mercurial gauge, and the dial marked by this gauge.

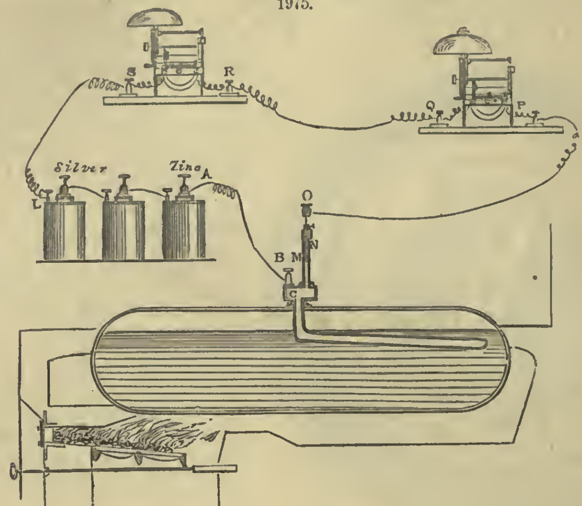
The common mercurial gouge is the surest and simplest of all gauges, but is often inconvenient on account of the space required for it, and is also ill adapted to locomotive purposes. It consists of a syphon tube partially filled with mercury, one end of which is subjected to the pressure of the steam whilst the other is open to the air. The pressure tends to displace the column in one leg and raises it in the other; the difference between the two shows the amount of pressure. Pressure gauges are equally adapted to show the pressure of a column of water as of that of steam.

Dun's Telegraphic Steam Gauge. Fig. 1975 represents so much of a steam-boiler as is necessary for our description. A tube descends into the boiler just below the proper water-line, and is secured to the sides. The branch C is fixed to the upper end, into which two tubes, B and N are fixed. The tubes and the branch C are filled with mercury to a fixed level at the proper temperature of the boiler. In the tube N is a wire set in such a manner that its lower end, which should be of platina, will come just above the quicksilver in the tube when it stands at the height which will be caused by the heat which should produce the pressure of steam desired in the boilers, and at starting, the apparatus is to be adjusted when the steam is at the working pressure in the boiler; and when the wire is so adjusted it is fixed by the set-screw O. From the upper end of the wire in the tube N, proceeds the wire to the bell apparatus P Q for the engineer, and at R S in the office; thence the wire proceeds to the battery A L. By this arrangement, when the heat in the boiler rises above that which is proper for producing the desired pressure of steam in the boiler, the quicksilver expands, and coming in contact with the platina

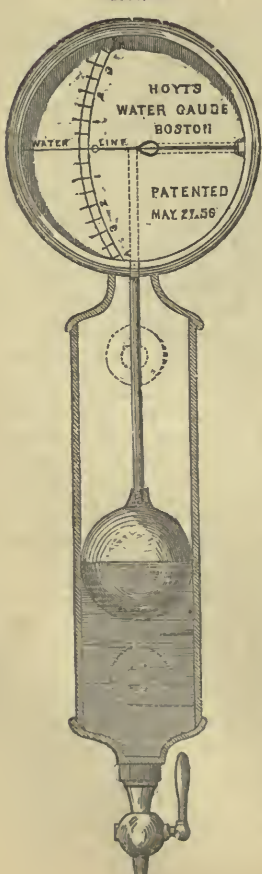
* Mr. Charles W. Copeland, 66 Broadway, is the general agent for the sale of the gage.

wire, completes the electric circuit, and the bells will continue to ring. If desired, the tube N may have a graduated scale to indicate the temperature at sight.

1975.



1976.



The accompanying engraving represents Hoyt's Water Gauge, partly in section. It is a simple mechanical invention for telling at all times, the position of the water in steam boilers. The dotted circles show the connection with the boiler; the cock at the bottom is a blow-out cock for the prevention of sediment. Its advantages are its durability, simplicity, and its constant and accurate indication of the solid water within the boiler, the foam not being dense enough to move or affect the float, which being filled with compressed air, is in no danger of loading or collapsing by the pressure upon its surface. The float is also directly connected with the indicating hand, by means of a lever and shaft working in a steam-tight case elevated above the water, so that no sediment can collect about the shaft, to prevent its always working with perfect ease and accuracy. No packing is needed, as the shaft in passing through the case to connect with the indicator, forms of itself, a perfectly steam-tight joint—not creating friction enough to prevent its working perfectly free at all times. It is easily applied to all kinds of steam boilers, locomotive, stationary, and steamboat.

One of the earliest and perhaps simplest of gauges to show the height of water in a boiler, is the glass tube gauge, of which an improved form, as made and sold by Charles W. Copeland, Broadway, New York, is shown in fig. 1977. It consists of a glass tube fitted between two chambers, the lower one of which is in connection with the water, and the upper one with the steam space of the boiler, the level of the water is indicated therefore directly in the tube.

The peculiarity of the gauge illustrated is in the cocks, the manner of filling the tube and of blowing off, shown fully in the section fig. 1978.

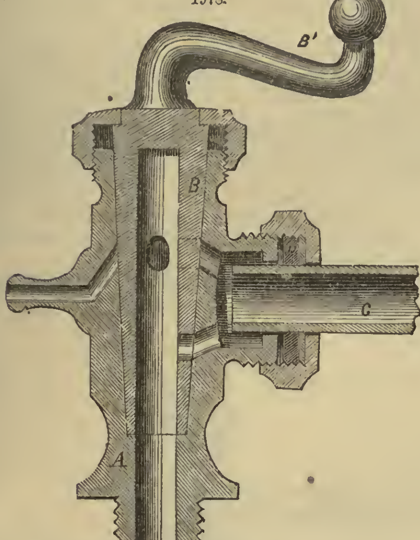
The glass tube is of thick, well annealed glass, packed at each end with a thin rubber collar, as shown in the section at D; this being made to press around the tube by compression in the stuffing box. The plug B, has two openings through its sides into the central hollow, and these may be so turned by the handle B′ that the tube may fill with steam or water, or both, or be blown through either above or below from the boiler.

Four stiff brass rods form a guard around the gauge, securing it from all ordinary danger of breakage and aiding to its appearance.

In England, and every where in Europe, glass gauges are universally used on locomotives as well as on stationary and marine boilers. They very rarely break, and seldom do any damage in

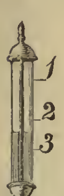
breaking. They are very simple, and show the water level with unerring accuracy. For locomotives especially, the motion of the engine shows the water almost constantly pulsating, and the water is certainly a better indication of its own level than any communi-

1978.

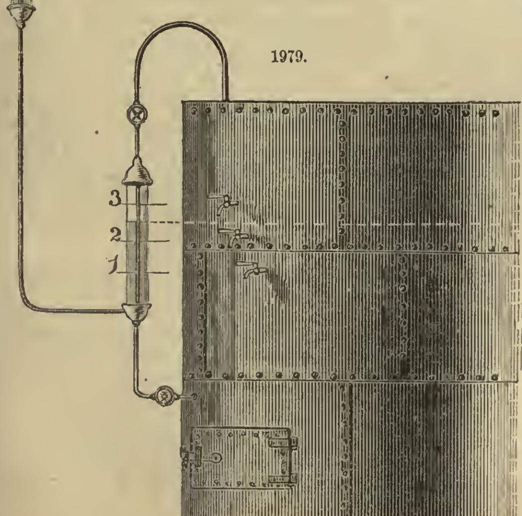


cated signals working by concealed apparatus can be. They can be entirely shut off if desired, while the time to renew a tube does not exceed five minutes.

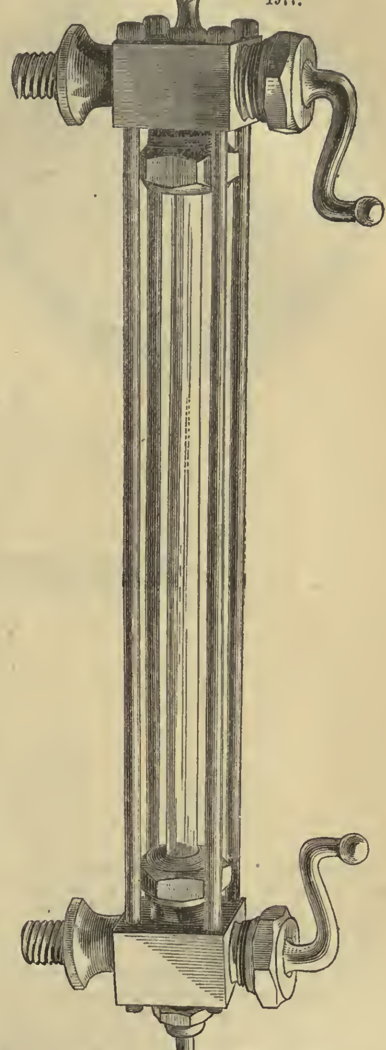
Fig. 1979 represents E. D. Rugg's patent *Water Gauge* attached to a boiler. It differs essentially from all other glass gauges in that the water in the glass tube has no direct communication with that in the boiler, and that a second gauge is attached at any convenient distance from the first, so that safety may be insured by having two observers. The gauge consists of a pipe connecting the steam and water spaces of a boiler, but not open at all exteriorly; this pipe is enclosed by a glass tube of sufficient length, and in position to show the fluctuations of the water. This tube is



1979.

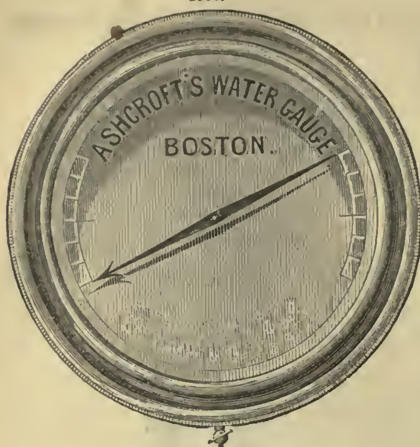


1977.



connected with another glass tube or chamber at any desirable level above that of the first. The cap of the second gauge is taken off, and water or other liquids is poured in till the lower gauge is full, the air being let out by means of a blow-cock. The boiler being fired, as the steam is formed in the boiler, it forms also in the first gauge, depresses the water to the level of that in the boiler, and raises it in the second gauge. Owing to the difference of temperature between the water and the steam, the space occupied by each in the glass tube corresponds with that in the boiler. As the water line falls in the boiler, it falls in the first glass tube but rises in the second, on this account, as will be observed the graduation is reversed.

1980.



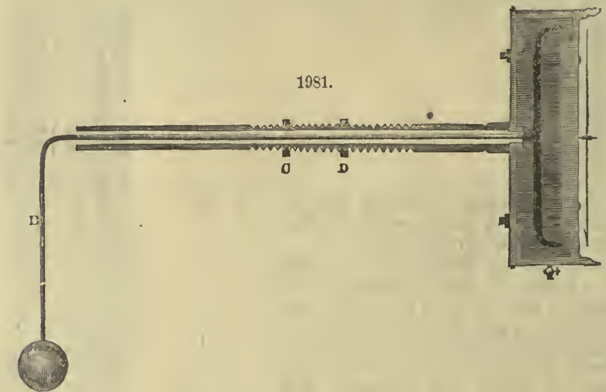
Ashcroft's *Magnetic Water Gauge*, for stationary and steamboat boilers, consists of a movable magnet in the inside of the boiler, which controls a needle on a dial outside of the boiler, the connection between the two being entirely magnetic.

Fig. 1980 is a front view of the dial, showing the needle and graduation. Fig. 1981 is a sectional view of the gauge.

A is a copper ball or float attached to a brass rod B, which passes through a pipe into the chamber of the gauge, on the end of which is affixed a steel magnet, having its positive and negative poles. The rod plays in the pipe with perfect freedom, having no *stuffing-box, valve connection, or packing of any kind about it;* hence there is no friction. The needle on the dial moves on a polished silver pin, and is controlled by the magnet. It will constantly indicate the level of solid water. Foaming or priming has no effect upon the gauge.

The scale on the dial will indicate a rise or fall of twelve inches of water, each degree measuring two inches.

1981.



Gauge-Cocks. Two or three small cocks fixed in front of the boiler of a steam engine, for the purpose of ascertaining the height of the water.

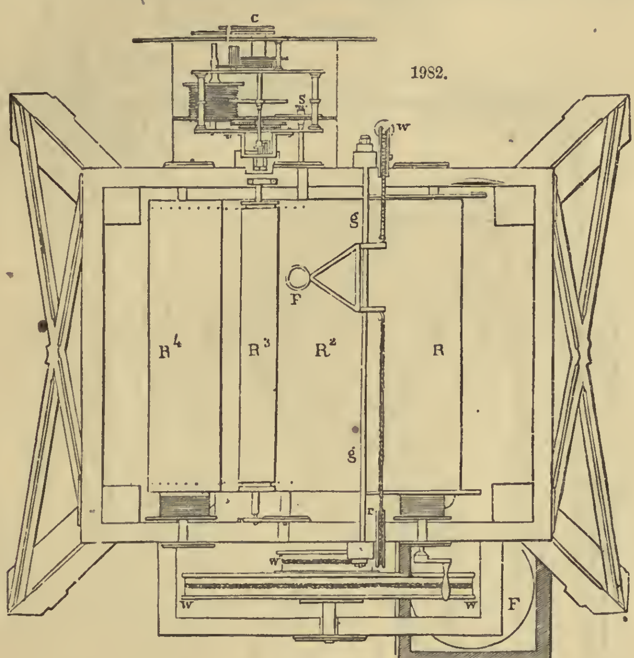
Gauge Railway. The distance between the rails; the most common gauge is 4 feet 8½ inches; the widest gauge in this country is the Erie Railroad, (6 feet,) and in England the Great Western, 7 feet.

Self-Registering Tide Gauge. Figs. 1982, 1983, and 1984, represent the side, rear, and top view of a tide gauge, devised by Mr. Saxton, of the Coast Survey Office. This gauge has been fully tested and approved by the experience of about eighteen months, in different localities with several gauges. In general terms, this tide gauge is arranged so as to record by a clock movement, the ordinate of time, by points pricked along the length of a running sheet of paper, carried forward by the clock-work, and intended for one month's record. The ordinate of tide height is recorded by connecting the recording pencil with a freely moving float, and so geering down the float motion as to limit the pencil movements to within one foot or the width of the sheet. A record curve results from these two movements which presents a perfect picture of the daily tide waves, in a series of maximum and minimum heights. By applying a reading scale, the actual tide height at any moment can be read off with nice accuracy. As we wish to give thorough and exact information, such as might serve for the construction and use of this instrument, we introduce the following description and drawings, with practical directions derived with slight modifications from official sources.

A float F, rising and falling with the tide, is connected by means of a chain or wire with a pencil point p, sliding on a straight guide g. If a slip of paper be moved beneath the pencil point at a uniform rate, the line will be divergent according to the rate of the tide, and if the paper be marked at regular intervals by the mechanism which impels it, the continuous curved line traced by the pencil will represent the rise and fall of the tide, so that the time and height may be accurately found at any instant. The particulars of the application of this principle are as follows:—The float and wire are protected from the action of the waves and currents by a tube which admits the water freely without allowing oscillation. The float is attached to a fine wire or chain, which connects it with the wheel w, upon the circumference of which it winds, and another small chain continues from the small pulley w', on the same shaft, and passing over the friction roller r, is hooked to the pencil frame. This small pulley reduces the play of the pencil to prevent an inconvenient width of paper, and is regulated by the amount of rise and fall of the tide.

To the other end of the pencil frame is attached a counterpoise w'', passing over a roller in the same manner. This weight causes the pencil to return as the float rises. The recording paper, being then wound compactly and accurately upon the cylinder R, passes beneath the pencil point and over the impelling cylinder R^2, geared to the hour wheel of a time-keeper. This cylinder has at its extremities, and with one foot interval, two circles of twenty-four equidistant conical points to each, arranged on its circumference, and as it revolves once in twelve hours, the points successively pierce and leave the paper at intervals of half an hour, at the same time that the paper passes over, and is re-wrapped upon the cylinder R^4. To insure the entrance of the points, a small roller R^3, rests upon the impelling cylinder, and prevents the paper from being lifted. The roller is grooved near the extremities, so that the conical points may not come in contact with the wood. The cylinder R^4, is urged forward by the weight E′, and the cylinder R is held back by the smaller weight E, so that the paper may constantly be kept well stretched. The excess of the weight E′ over E is sufficient to overcome the friction of the system of rollers, so that the clock has merely to regulate time. Upon the axle of the impelling cylinder is a clamp screw S, by which it may be detached from the clock. To put the machinery in motion,

1982.



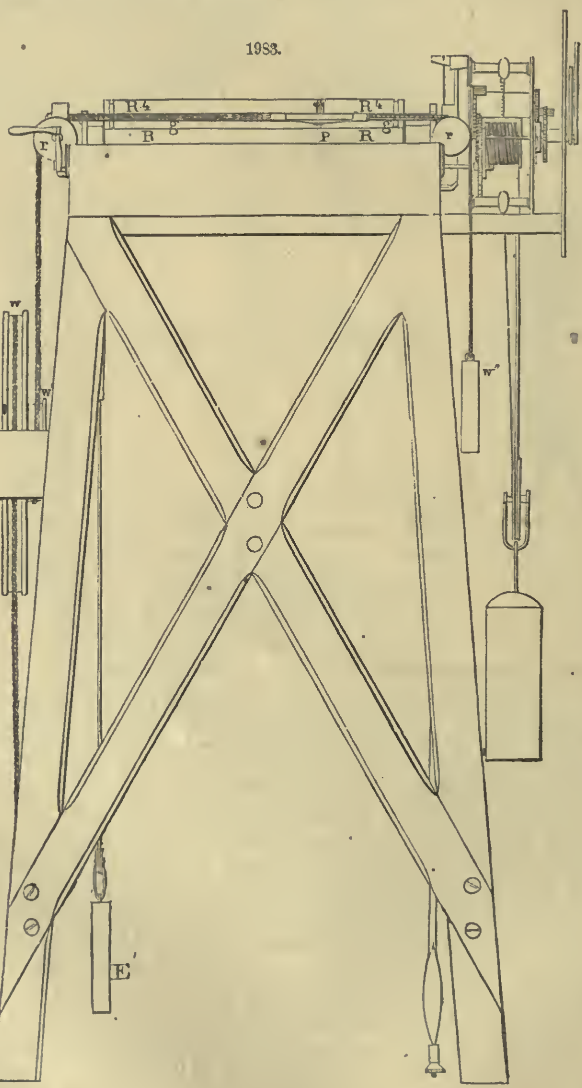
the pencil and one of the conical points being brought accurately in the same vertical line at any exact hour, the cylinder is then fastened to the clock by means of the clamp screw, when, as it moves with the clock, it completes a revolution in twelve hours; the conical points will consequently mark exact hours and half hours, whilst the line traced by the pencil will show the corresponding heights of the tides according to the scale to which the machine is adjusted.

The following points require attention in adjusting this gauge:—I. The counterpoise should be rather more than sufficient to balance the chain or wire, taken as they will be, at lowest tide. The strain upon the pencil is very slight, but when the rise and fall is great, the chain or wire should be as fine as possible, that the counterpoise may not be inconveniently heavy. II. The chain or wire to which the float is attached, should be so adjusted upon the large wheel that the curve of rise and fall will be traced on the paper midway between the lines of dots. One or two days' trial will locate this curve of rise and fall sufficiently well for the chain or wire to be permanently pinned. III. A conical point should be brought accurately in a line with the pencil, and the clock started at an exact hour or half hour. IV. That the gauge may be disturbed as little as possible, at least one full month's supply of paper should be wound upon the receiving cylinder at the beginning of the month.

To guard against accidental disturbances and jars, the structure upon which the gauge is erected should be as firm as possible. The superstructure for protection against the weather and other disturbing causes, need only be large enough to allow free access for attendance on the gauge. The box for containing the float should be water-tight, below water, except an adjustable orifice, which may be made by a series of holes about an eighth of an inch in diameter, covered in part by a slide, and it should extend up to the floor on which the gauge rests, that the free action of the float and its connecting wire or chain may not be endangered by obstructions falling into the box. Having so adjusted the wire or chain as to give the midway position on the paper to the record curve, particular care should be taken to prevent its being altered, since any change in its length or points of attachment to the wheel will vary the relation of the record curve to the permanent Zero. All gauge records should be carefully re-

ferred to some permanent Zero, or bench mark well cut into the stone, or reference mark, and this Zero or bench mark should be fully and precisely described in the file of tide records, as also all changes in the mark and in the Zero of the gauge itself, as referred to the mark. A common staff gauge should always be erected in connection with a self-registering gauge, and as near by as convenient; it being then simply necessary to obtain by careful levelling, the reading of the bench mark on the staff, when it reads Zero at its own reading level, and then to compare the simultaneous indications of the two gauges, for the starting point of the record curve readings. These gauges should have such positions as to receive the full effect of the tide, and when from freezing or other causes the registering gauge ceases to work, the staff gauge must be used for hourly and high and low water observations in the usual manner. The record sheet should always bear upon it the names of the station and observer, the number and scale of the gauge, the dates of beginning and end of the record, the 12 M. dot of each fifth day clearly dated, and full notes of the time and causes of all breaks in the record, and of all new starts with the interpolated staff gauge readings during the record gaps.

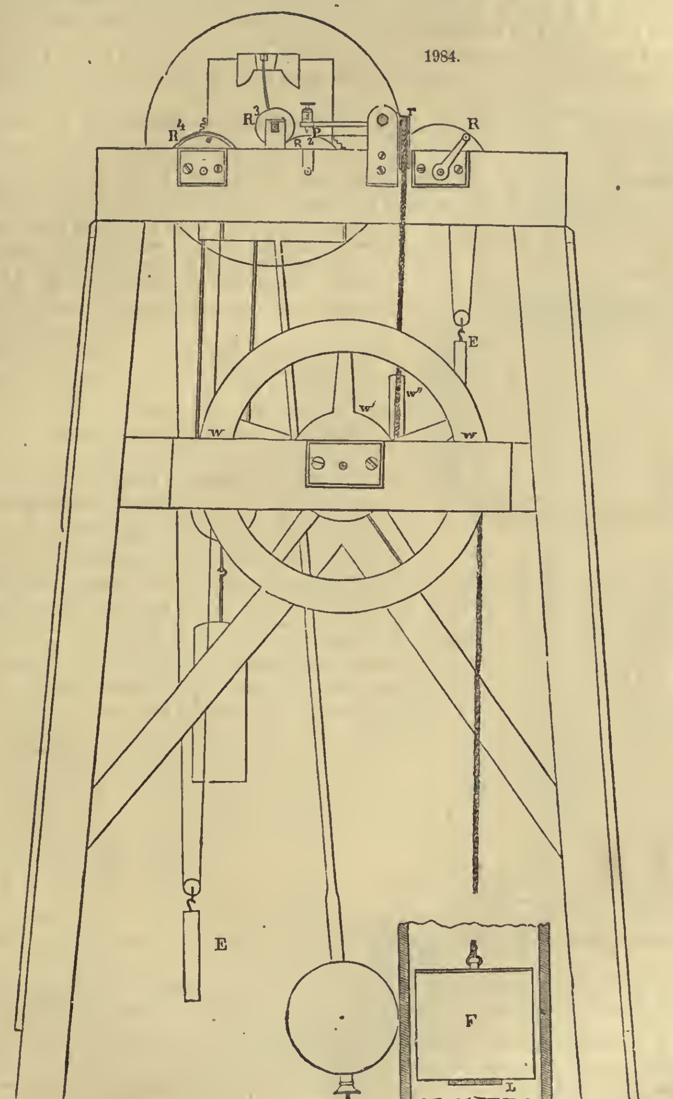
1983.



After taking these precautions and getting the instrument well started, each Coast Survey Observer is required to visit his station every day until he is sure all is going right, when it is deemed sufficient for him ordinarily to visit it every other day, observing the following directions. "1. The steel rod to which the recording pencil is attached, should always be kept perfectly clean and free from rust; for this purpose it may be rubbed with oiled cloths every week, care being taken that no oil be left on the

rod, or allowed in any way to touch the arms which support the pencil resting upon it. 2. If in consequence of a continuation of storms, the tide should fall so low as to render the counterpoise insufficient to keep the chain well stretched, a small additional weight may be added. When the rise and fall is great, or very much influenced by the winds, this may sometimes be necessary; but as there is little strain upon the pencil, the person locating the gauge should, in the first place, make the counterpoise sufficient to embrace all but very extraordinary tides. Proper attention to the two foregoing paragraphs

1984.



will insure an unobstructed motion of the pencil. 3. The clock should be made to keep mean solar time, being corrected to this effect, whenever it is necessary, by a sun-dial or a meridian mark with the equation of time applied, or by such other means as may be found available. 4. Should the clock become disordered, it is not desirable for the observer to disturb its mechanism. Timely notice may always be given to the assistant in charge of the office when any repairs are needed. 5. The clock should never be stopped unless from absolute necessity, or from some unavoidable accident. Whenever it is so stopped, the time and corresponding hour dot upon the paper should be distinctly marked. When it is again set in motion, the first hour dot, together with the corresponding time, should be noted in like manner. 6. The hour dot corresponding to 12 o'clock M., upon the fifth day of every month should be marked. 7. The sides of the sheet corresponding to the high and low water should be marked respectively H. W. & L. W.

The record sheets are read in the office by the aid of a special table, the sheet being run between two

overlapping guides and under a reading scale fixed transversely. A small transparent scale of radiating lines is used for subdividing the half hours, thus giving the means of very close readings about the high and low waters.

GAUGE. See MANOMETER.

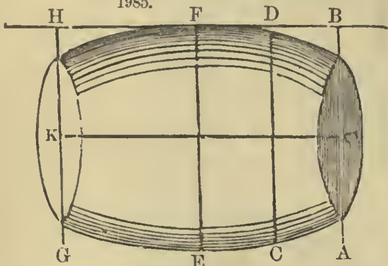
GAUGING. A term in mensuration, determination of size or capacity.

Cask Gauging. The nearest method to the truth that has hitherto been practised is, by taking the diameter at an equal distance from the head and bung. Lay a straight-edge touching the bulge of the cask in the middle, as H B at F fig. 1985, the internal length and bung diameter being known; set off on H B from the centre F of the cask towards either end, one quarter the internal length as at D; then the distance from D to the stave, added to the thickness of the stave and doubled, will give the excess of the middle diameter above the bung, and this taken from the bung diameter will give the middle diameter.

Let the bung be 32 inches, the distance from D = 1 inch, and the thickness of the stave =.75 of an inch; what is the middle diameter? $1+\cdot75=1\cdot75$, and $1\cdot75\times2=3\cdot5$; $\therefore\ 32-3\cdot5=28\cdot5$, the middle diameter O P.

When this diameter is obtained, and having the head diameter, the bung, and internal length of the cask, observe the following rule: To four times the square of the middle diameter, (or to twice the middle diameter squared, which is the same,) add the squares of the head and bung diameters; the sum multiplied by one-sixth the length, and the product divided by 353·035, will give the content in gallons.

1985.



Taking the middle diameter as found above at 28·5 inches, the head = 24, the bung = 32, and the internal length = 42 inches respectively; what is the content?

$28\cdot5\times2=57$ and $57^2 \quad =3249=$ square of twice the middle diameter,

or $(28\cdot5)^2\times4 \quad =3249=$ the same.

Then $(\text{head diameter})^2=(24)^2=\ 576$

Also $(\text{bung diameter})^2=(32)^2=1024$

$\overline{4849}$

$\frac{1}{6}$ of the length $=\frac{1}{6}$ of $42=\quad 7$

353·035)33943(96·1463 gallons.

Or the rule may be expressed thus:

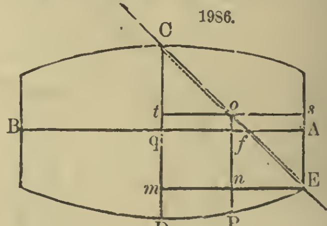
To four times the area of the middle diameter, add the areas of the bung and head diameters; the sum multiplied by one-sixth the length, will be the content.

Another method of finding the diameter in the middle between the head and bung diameters, is by putting the gauging-rod C E into the bung at C (when the axis A B is horizontal;) let a ring be fixed at O, in the middle of C E, through which the plumb line C O P moves freely; in this manner O P is determined. To find the middle diameter: to twice O P add the head diameter, and half the difference between bung and head diameters, and subtract from the sum the bung diameter, thus: To find the content of a cask, whose bung and head diameters and length are 36, 28, and 44 inches respectively; also the length taken with a plumb = 18·12 inches.

$$\begin{aligned}
18\cdot12\times2 &= 36\cdot24\\
(\text{head diameter}) &= 28\cdot00\\
\frac{36-28}{2} &= 4\cdot00\\
&= \overline{68\cdot24}\\
(\text{bung diam.}) &= 36\cdot00\\
32\cdot24 &= \text{the middle diameter.}
\end{aligned}$$

Then we have the content = 129·5697 gallons.

1986.



Notwithstanding the apparent simplicity of this mode of finding the contents of casks, in practice it becomes in some degree troublesome, and its accuracy depends much on the manner in which the distance O P is taken.

But if O P be obtained correctly, (at the same time observing that the cask lies level, that is, when the axis A B is horizontal,) it approaches very near the truth.

If the cask be spheroidal, the content may be obtained by taking the length of a diagonal with a rule commonly called Branan's, without having the head, bung, or length: apply the rule or rod from the centre of the bung to where the end meets the stave at the opposite side—as from C E fig. 1986; then the number on the rule in the centre of the bung will be the content in gallons.

The rule or diagonal rod here spoken of, is constructed for the middle frustrum of a spheroid, therefore it will not give the true content unless the cask be of that particular form; and here it falls under the objection that we have too many of the old methods, for we have no criterion whereby to judge whether a cask is spheroidal or not.

Other diagonal rods can be constructed for casks of other varieties, as solids are to each other as the cube of their like dimensions; but these rods would be subject to the same objection as the other in use.

If the diagonal rod be applied to the head diameter of a cask, twice the diagonal number which measures that diameter will be the content in gallons.

There are many other rules given in works on gauging, but these problems are now most frequent solved with the aid of SLIDE RULE, which see.

GAUGE. A mixture of fine stuff and plaster, or putty and plaster, or coarse stuff and plaster; used in finishing the ceilings and for mouldings, and sometimes for setting walls.

GEER-CUTTING MACHINE, BEVEL. For the cutting of bevel geer an admirable machine has been recently invented and patented by George H. Corliss, of Providence, R. I., in whose shop (Corliss, Nightingale & Co.) it is in successful operation. From the specifications of the patentee we extract the following full and clear description of the machine, its distinguishing characteristic, construction, and operation.

Fig. 1973, plan of the machine.

Fig. 1974, a side elevation.

Figs. 1975 and 1976, enlarged cross sections, taken at the line A *a* of Fig. 1973; the former with certain parts removed.

Fig. 1977, another cross section at the line B *b* of Fig. 1974.

Fig. 1978, a vertical cross section at the line C *c* of Fig. 1976.

Figs. 1979 and 1980, enlarged end and side views of the cutter and carriage.

Fig. 1981, an enlarged separate view of the hinge which forms the axis of the guide-bar on which the cutter carriage slides.

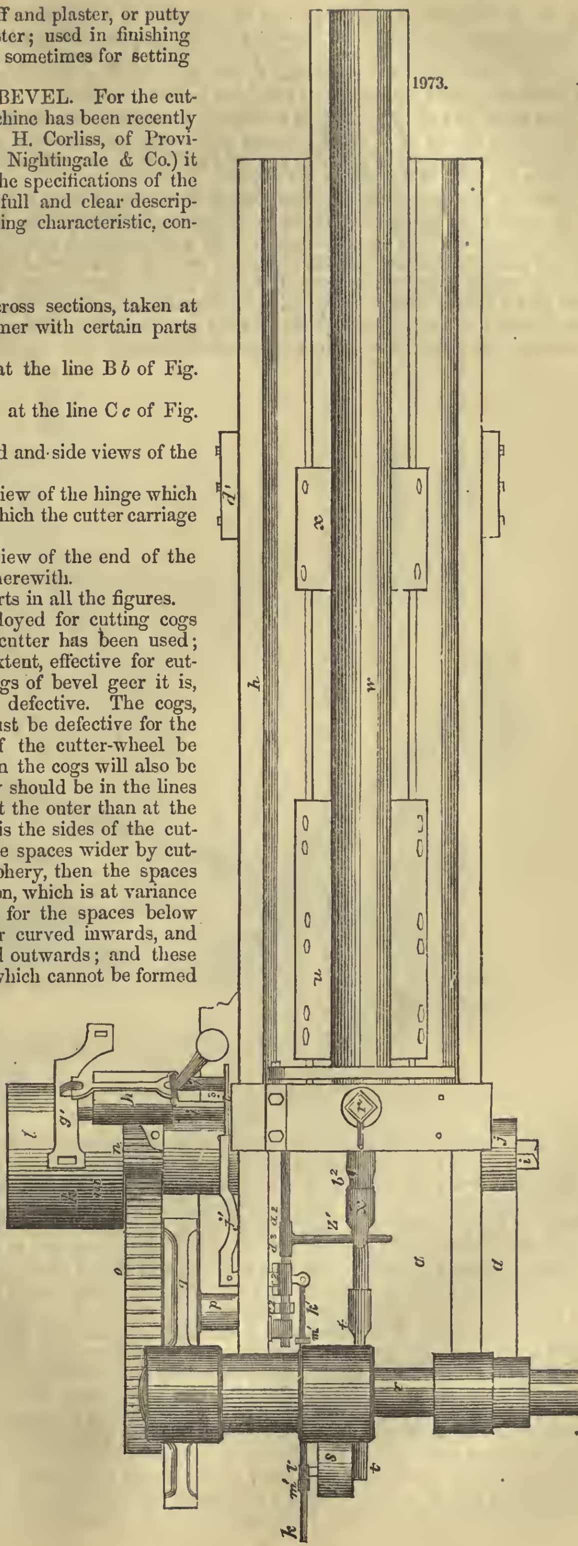
Fig. 1982, an enlarged separate view of the end of the guide-bar, with a stem connected therewith.

The same letters indicate like parts in all the figures.

In the machines heretofore employed for cutting cogs of toothed wheels, a rotating burr cutter has been used; and although this is, to a certain extent, effective for cutting spin geer, yet in cutting the cogs of bevel geer it is, from the very nature of the case, defective. The cogs, when cut with a rotating cutter, must be defective for the following reasons: if the sides of the cutter-wheel be parallel, the space cut out between the cogs will also be parallel, whilst in bevel-wheels they should be in the lines of the radii, that is, farther apart at the outer than at the inner periphery; and if to avoid this the sides of the cutter-wheel are bevelled, to make the spaces wider by cutting deeper towards the outer periphery, then the spaces will be wedge-formed in their section, which is at variance with the proper formation of cogs, for the spaces below the pitch-line should be vertical, or curved inwards, and from the pitch-line upwards curved outwards; and these curves should be sections of cones, which cannot be formed by a rotating cutter, which, from the very nature of its operation, will make the same curve from end to end of the cog.

The object of this invention is to avoid this objection; and for this purpose the first part of the invention consists in the use of a reciprocating cutter, governed by a guide-bar on which the cutter carriage slides, and which has its axes of vibration to adapt the cutter to the required depth of cogs at the apex of a cone corresponding with the bevel of the wheel to be cut, whether such axes be fixed or adjustable to wheels of different sizes, that all the cuts may be in the direction of the radii.

The second part of the invention consists in combining the guide-bar, on which the cutter carriage runs, with a secondary frame hinged to the main frame outside of the circle of the largest wheel intended to

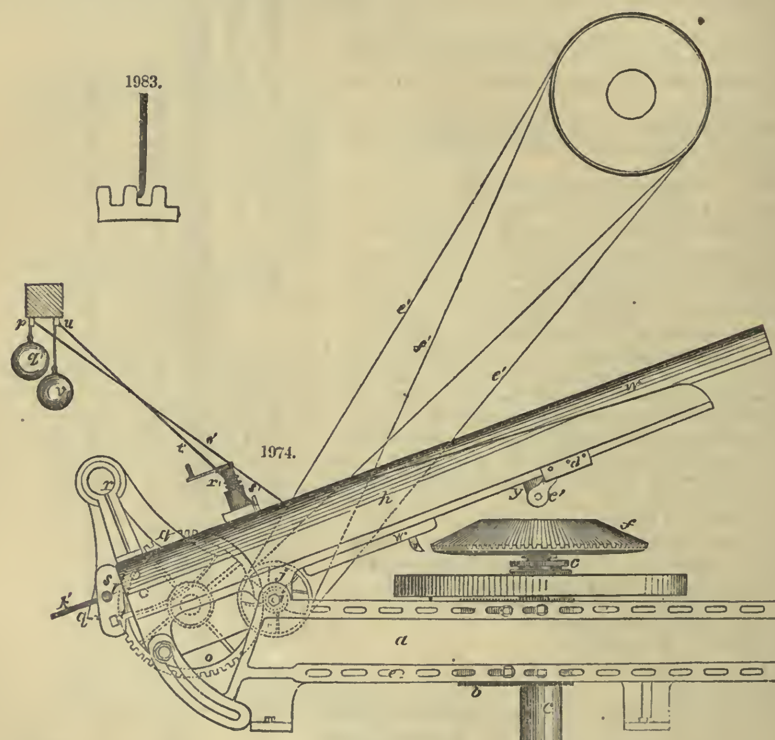


1973.

be cut in the machine, that the axis of vibration of the guide-bar may be elevated or depressed to adapt the machine to different bevels; and that the main driving shaft, which communicates motion to the operative parts of the machinery placed at the hinged end of the said frame, may be in the line of the axis of vibration of the said frame, that the vibration thereof may not change the relative position of the driving shaft and the parts receiving motion therefrom.

The third part of the invention consists in combining with the guide-bar a guide-plate, against which it bears by means of a weight, spring, or the equivalent thereof, so that as the guide-bar descends to give the proper depth to the cogs, the said guide-bar shall follow the curve of the guide, and thus determine the form of the face of the cogs.

And the last part of the invention consists in making that part of the rear end of the guide-bar which rests against the guide, movable, so as to have an endwise motion, in or on the said bar, in the direction of its length; the said movable part or stem being bevelled back of where it rests against the guide, and so connected, either with the guide-bar or some other part of the machinery, that at the time of the cutting motion it will move forward, that its bevelled surface may be brought in contact with the guide and give a lateral motion to the guide-bar, to relieve the cutter from the surface of the cog that is being cut, to admit of its moving back clear of the cog; and then, at the end of the return motion, a reversed motion to bring the cutter in the proper line for cutting.



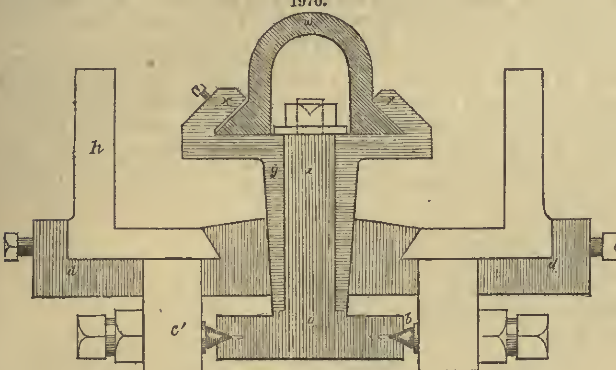
1983.

1974.

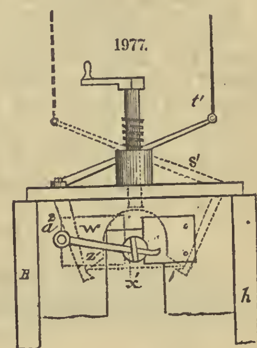
In the accompanying figures, *a* represents the main frame of the machine, to the inside of which is adapted a frame *b* that carries the spindle *c* of an index-plate, made in the usual manner. This frame *b* is secured to the main frame by the bolts *d d* that pass through elongated holes *e e* in the side pieces of the main frame; and as there are several of these holes along the frame, the index-plate can be moved to any place required on the main frame, to adapt the machine to wheels of various sizes. The upper end of the spindle *c* is adapted, like other cutting engines, to receive the wheel *f* to be cut. A secondary inclined frame *h* is provided near one end with a shaft *i*, the journals of which run in boxes *i j* at the end of the main frame, so that the secondary frame can be inclined to any desired extent with the axis of the index-wheel to determine the bevel of the cogs to be cut. And the extreme rear end of the secondary frame is provided with a bolt and temper-screw that pass through a segment mortice in the main frame, by means of which the secondary frame may be secured and held in place at any inclination required. The shaft *i* of the secondary frame extends out sufficiently on one side to receive one loose pulley *k*, and two fast pulleys *l m*, one on each side of the loose pulley. The loose pulley *k* turns freely between and on the barrel of the other two in a manner well known to machinists. And the inner end of the fast pulleys *l m* is provided with a pinion *n*, which engages and carries a cog-wheel *o* that turns on a stud-pin *p*, and the arbor of the wheel carries a pinion (see dotted line in Fig. 1974) that engages and carries a sector-rack *q* on the end of a rock-shaft *r*, provided with a pendulous arm *s*, to the lower end of which is joined a connecting rod *t* that takes hold of the rear end of a carriage *u*, (as seen in Fig. 1980,) to which is secured the cutter *v*, in any appropriate manner. The carriage slides

on a guide-bar *w* properly formed for this purpose, as shown in the figures, and in turn this guide-bar slides inways *x*, connected by a socket *y* with a stud *z* that projects from an arbor *a′* which turns on pivot screws *b′ b′*, that pass through the two ears *c′ c′* of a plate *d′*, secured by bolts or screws to the side pieces of the secondary frame, so that by shifting these screws the plate can be moved along the secondary frame, as the index-plate and its spindle can be moved along the main frame to adapt the machine to the cutting of wheels of various diameters. The guide-bar is thus connected with the secondary frame by a universal joint, and the connection of the universal joint with the secondary frame can be shifted to adapt the machine to the cutting of wheels of different sizes, and as the axis of the vertical vibration of the guide-bar must always be in the line of the axis of the index-plate, the mode of shifting either the one or the other must be such as will admit of accurate adjustment. For this purpose the holes in the main frame, through which the securing bolts pass, are elongated. The machine is driven by two belts *e′ f′*, one being crossed, and the two governed by a double belt-shipper *g′*, so formed that when the direct belt *e′* runs on the pulley *m*, to give the cutting motion to the cutter carriage by the connection of parts from the pinion *n*, the crossed belt *f′* runs on the loose pulley *k*, and when the belts are shifted at the end of the cutting motion, to reverse the motion, the crossed belt runs on and

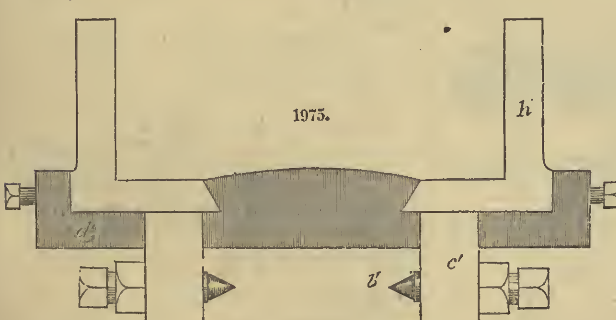
1976.



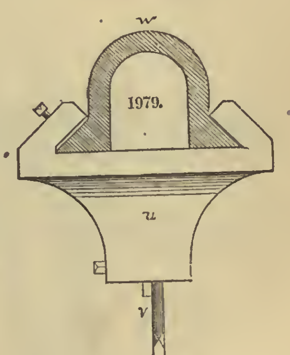
1977.



1975.



1979.

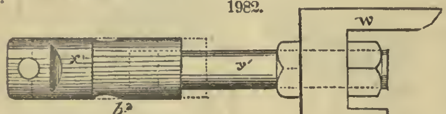


carries the pulley *l*, and with it the cutter carriage by the same connections, and the direct belt *e′* then runs on the loose pulley; or, if desired, this arrangement of belt may be reversed. In this way the desired motions are given, and the shifting of the belts is effected in the following manner: The belt-shipper is attached to the outer end of two rods *i′ i′* that slide in a plate *h′* attached to the frame, and these way-rods *i′ i′* are connected by a cross-bar i^3 with one arm of a right-angle lever *j′*, the other arm of which passes to the inside of the main frame, and is there jointed to a rod *k′* which passes through a thimble *l*, jointed to the pendulous arm *s* that communicates motion to the carriage. The rod *k′* is provided with two adjustable stops *m′ m′*, on each side of the thimble, and at such distance apart that when the pendulous arm *s* moves forward to effect the cutting motion, towards the end of this motion the thimble strikes one of the stops *m′*, and shifts the belts to give the return motion, towards the end of which the other stop *m′* is struck to re-shift the belts. In this way, by simply varying the distance between the two stops *m′*, any desired range of motion can be given to the cutter carriage, to adapt it to the length of the cogs to be cut.

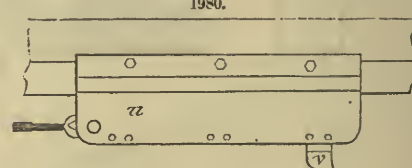
As before described, by reason of the universal joint connection, the guide-bar is free to move either vertically or horizontally, and with it the cutter carriage which slides on it. Its rear end is suspended to a cord *o′* which passes over a pulley *p′* with a counter weight *q′* attached to it, by which it is held up against the end of a set screw *r′*, the turning of which will therefore determine the depth of cut to be made by the cutter. This guide-bar is also borne laterally by means of a bent lever *s′*, (see also Fig. 1977,) one arm of which acts against it, and the other attached to a cord *t′* that passes over a pulley *u′* and is provided with a weight *v′*. This weight always tends to bear the guide-bar in one direction, horizontally, and against a guide-plate *w′*, one edge of which is formed so as to determine the form to be

given to the face of the cog, and as this plate can be removed, others may be substituted to suit the various and desired forms of cogs. The rear end of the guide-bar, however, does not bear against this guide-plate, but, instead of this, there is a stem x' with a socket in its forward end that slides accurately, but freely, on a projection y', Fig. 1982, from the rear end of the guide-bar, so that one can slide on the other longitudinally; and this stem it is that bears against the guide-plate. The rear end of the stem is looped to receive the arm z' of a slide a^2. It will be observed that whilst the stem is in the position represented in the drawings, as the rear end of the guide-bar is moved up and down to cut the depth of the cog, the stem x' follows the curvature of the guide w', and therefore communicates a corresponding motion to the point of the cutter in a direction converging to the centre of the universal joint, on which the guide-bar w vibrates, and that, therefore, any curve to be given to the cross section of the cog will be gradually reduced as it approaches the axis of the wheel. But when the cutter is to be moved back, it is necessary that it should run clear of the metal, and for this purpose the stem x', back of the part which is represented as bearing against the guide-plate, is curved inwards, or bevelled as at b^2, so that when this part is brought in contact with the guide-plate a slight lateral motion is given to the guide-bar sufficient to relieve the cutter. The required endwise motion for this purpose is given to the stem by the operation of shifting the belts to reverse the motion of the cutter. The inner arm of the lever j', of the belt, carries a box c^2, that slides freely on the slide a^2, and towards the end of the forward motion of the cutter carriage; this box strikes against a stop d^2, from which the arm z', connected with the stem x', projects and forces forward the stem to the distance required to bring the bevel b^2 against the guide-plate w' to relieve the cutter. The cutter carriage then runs back and towards the end of this back motion; the box on the lever of the belt-shipper strikes another stop e^2, on the slide a^2, and moves back the stem to bring the cutter in the proper line for making its cut. In this way at each operation the cutter is relieved and returned to its proper position for cutting. The cutter is fitted in any desired manner in a socket in the carriage, and when it is desired to cut cogs of the form represented in the enlarged Fig. 1983, the cutting edge of the cutter must be bent forward, as shown in that figure.

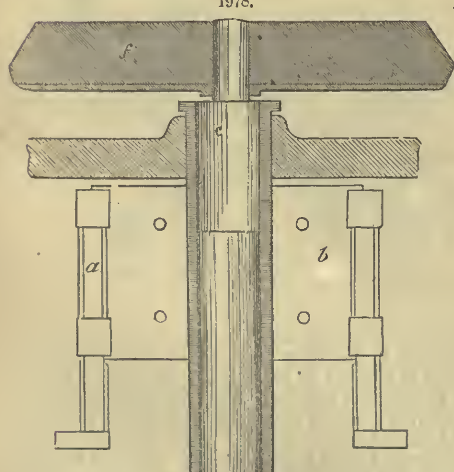
1982.



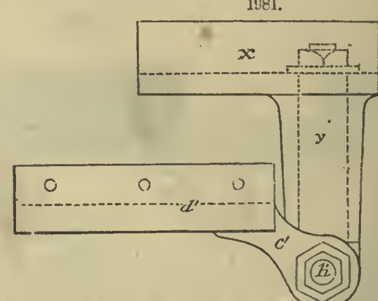
1980.



1978.



1981.



In a machine constructed and operating on the principle of this invention, every cut converges to the apex of a cone that represents the bevel of the wheel, and therefore the cogs, and the spaces between them, will gradually and in the true proportion diminish from the outer to the inner periphery. Thus far as to the mode of operation of the machine for cutting the faces of the cogs on one side; but as each cog has two faces on opposite sides, so soon as one face of all the cogs have been cut, the machine must be reversed to cut the other side, and for this purpose it is simply required to reverse the cutter V, the guide-plate w', and the lever s. The reversed position of these parts is shown in dotted lines in Figs. 1977 and 1979. By the shifting of these parts, it will be observed that the machine will cut the reversed side of the cogs. The lower end of the cutter should be properly formed to give the required shape to the bottom of the cogs.

The patentee claims, first, The method of cutting the cogs of bevelled wheels by means of a reciprocating cutter that moves in or on a slide, or slides, that vibrates on an axis that coincides, or nearly so, with the apex of a cone representing the bevel of the wheel to be cut, substantially as herein described,

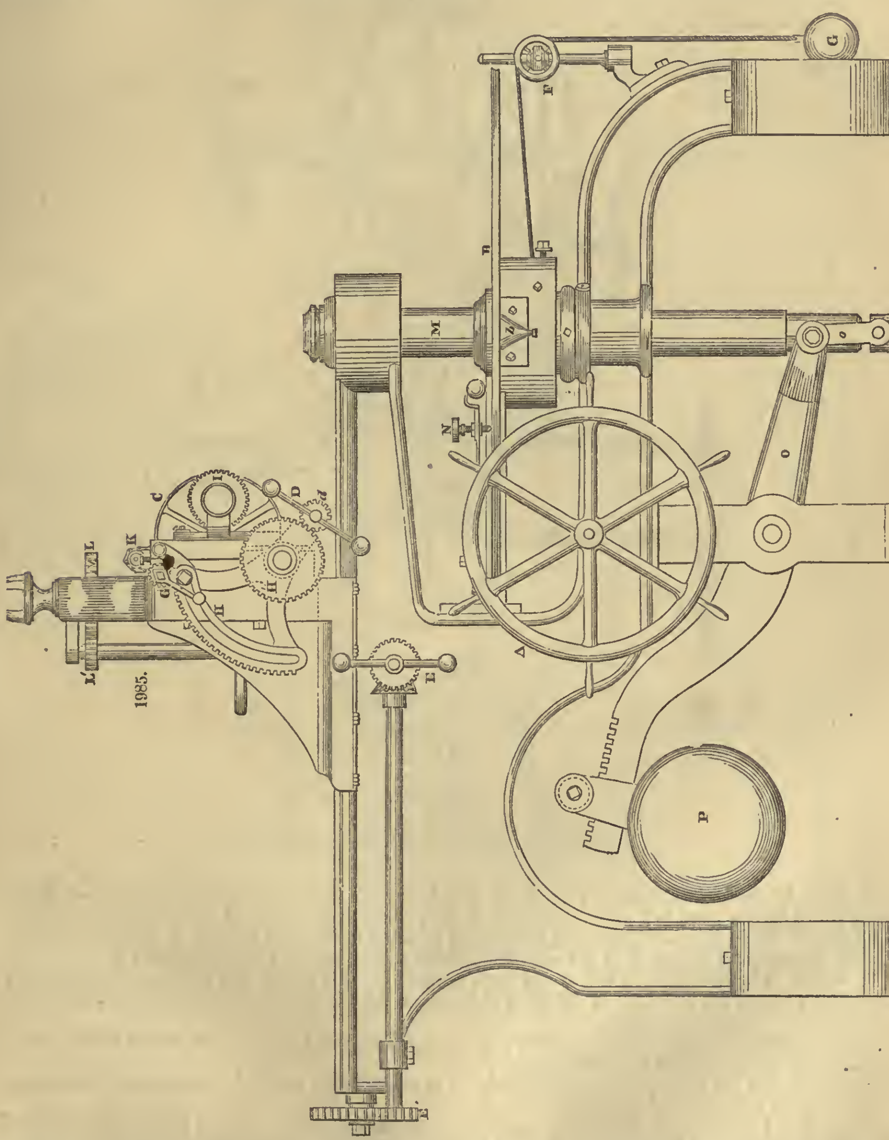
by which vibration the depth of the cut is determined, and irrespective of the adjustment of the axes of vibration as described.

Secondly, The guide-bar, (or its equivalent,) on which the cutter carriage runs, and having its axis of vibration for the depth of cut, as above described, when combined with a secondary frame jointed to the main frame at some point outside of the circumference of the wheel to be cut, that the machinery may be adapted to the cutting of cogs on various bevels.

Thirdly, In combination with the guide-bar, having a universal joint, or the equivalent thereof, and operated substantially as described in combination with the guide-plate, to guide the cutter and determine the form of the face of the cogs, as described.

And lastly, Making that part of the guide-bar which rests against the guide-plate to determine the form of the face of the cogs separate from, and movable on, the guide-bar, and properly bevelled to relieve and clear the cutter for its back movement, substantially as described.

GEER-CUTTING ENGINE. Figs. 1984 and 1985 are front and side elevations of a geer-cutting engine, as built by the Lowell Machine Shop, sufficiently large to cut a geer 7 feet in diameter and 8



1985.

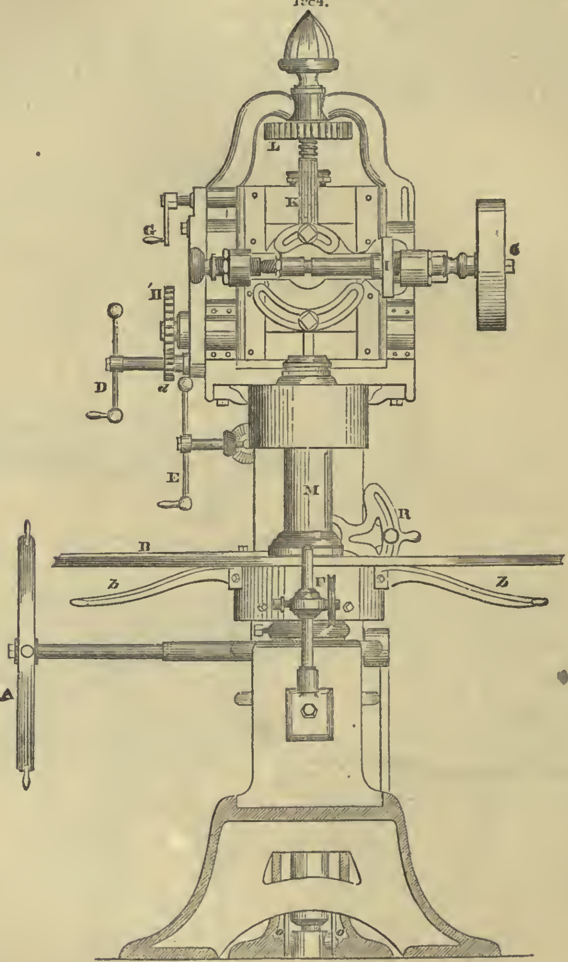
inches face. This is a heavy and strong-built machine, adapted to cutting spiral spur and bevel geers without any additional fixtures.

M is the spindle to which the geers are fastened when being cut, and to which is attached the dial

plate B, on the upper surface of which are drilled circular rows of holes very accurately *spaced off;* by means of this, and the spring and point N, Fig. 1984, the geer is divided into the required number of teeth.

A, hand-wheel for raising and lowering spindle M when cutting small geers. For cutting large spur or bevel geers, the geer remains stationary, and the head to which the cutter is attached is traversed up and down by means of the crank D, which moves the pinion *d*, geering into a larger geer H, on chain pinion-shaft. An endless chain running up over a pulley K is attached to the plate, to which the cutter shaft stand is attached. This stand can be turned around at any angle for spiral or worm geers.

1984.



R, guide for spindle when cutting worm, or slightly spiralled geers. When spiral geers of greater angle are to be cut, there is a circular inclined plane of plate steel screwed to the cylindrical part of the yoke, (under the dial,) which bears on a friction roll attached to the main frame. It is kept against this roll by means of the weight G, at the end of the string passing over the grooved pulley F.

P, weight to balance spindle M and the geer, being cut. This weight has a pinion playing into the rack on the top of the long arm of the lever O, by means of which it can be moved forth and back to balance geers of different weight.

G′, crank and pinion geering into segment, for setting the head at an angle for cutting bevel geers.

C, driving pulley coupled to cutter shaft.

L, geer on nut for raising the cutting head. It is worked by a pinion L′ on the end of the upright shaft, to which a hand-wheel is attached.

E, crank and bevel geers which communicate with the screw inside of frame, by means of the geers E′. Turning this crank moves the head stock to different positions, for different sized geers.

b b, arms to which the cord and weight are attached when cutting spiral geers.

This machine is a very convenient one to work at, as the operator can stand in one position and command every part of it.

Figs. 1986, 1987, another form of geer-cutting engine for cutting bevel, spiral, and spur geers, also made by the Lowell Machine Shop.

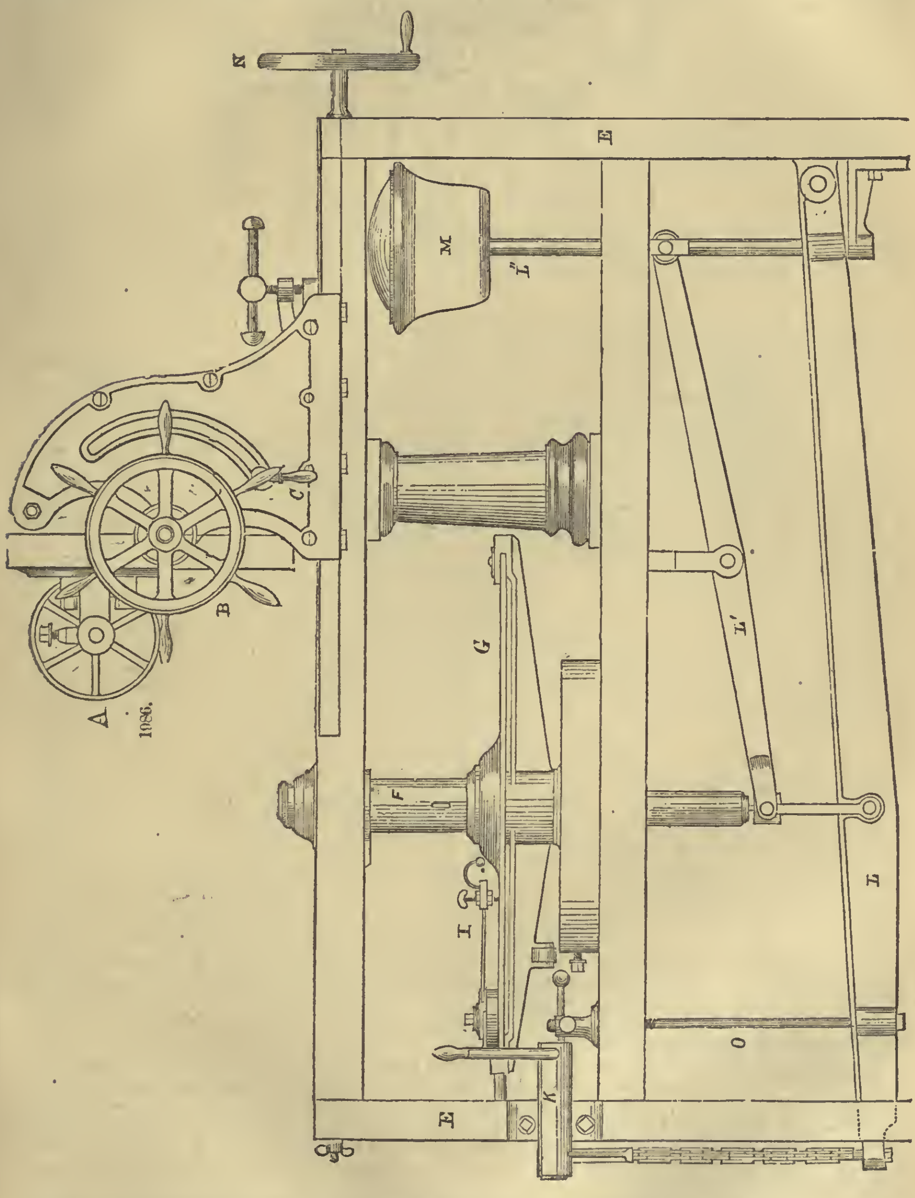
Fig. 1986, side elevation.

Fig. 1987, front or end elevation.

E E are the end standards which form part of the frame.

D, swing slide, in which the cutter head slides when cutting bevel geers.

B, hand-wheel on pinion shaft passing through the axis of the swing slide D, which has a pinion geering into a rack on the back side of the cutter head, for traversing the cutter.



C, handle nuts for fastening the swing slide in the circular slot at any angle required.

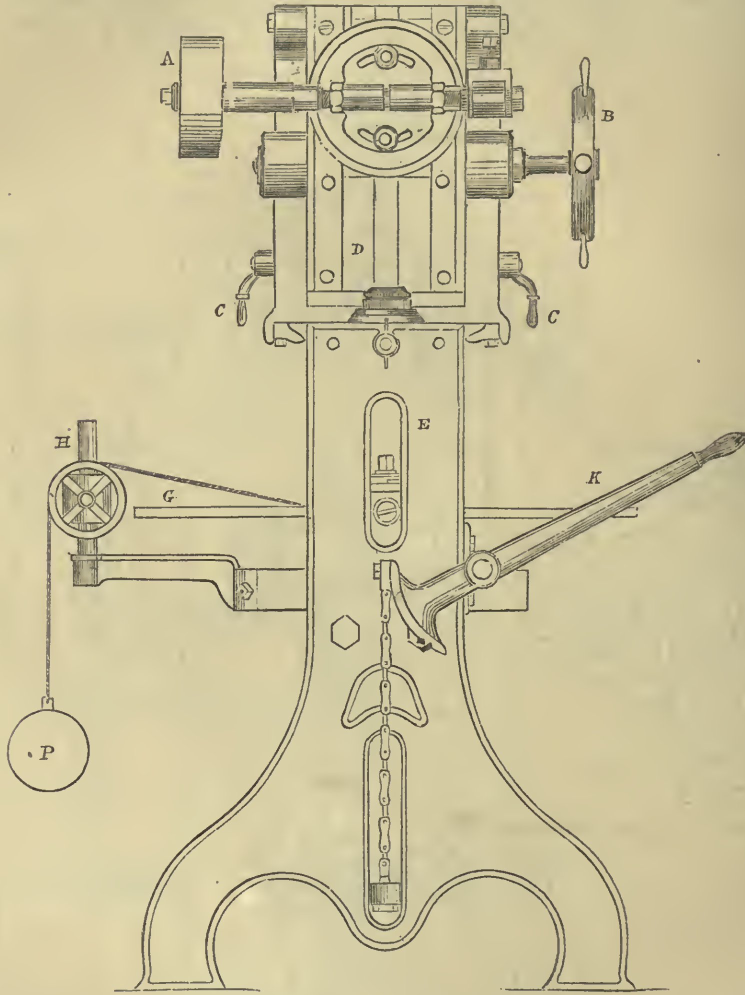
A, driving pulley on the shaft that drives the cutter shaft. This pulley and shaft are fixed. The cutter shaft can be taken out without throwing off the belt, as the two shafts are connected together with a clutch coupling.

N, hand-wheel on screw for traversing cutter head to suit geers of different diameters, or in cutting worm geers, &c.; to the left of N are seen the screw and lever for fastening the head.

G, dial or index, having rows of holes of different numbers drilled on its face, which can be divided by means of the point and spring I, so as to cut any number of teeth wanted.

K is a hand lever for raising spindle F and dial with the geer while cutting. This lever is on one end of a short shaft passing through a stand, and on the other end there is a quadrant, to which a chain is attached, that connects with the long lever L, on which the spindle stands.

1937.



L″ is a balance lever weight to counterbalance the spindle and dial, and the weight of the geer which is being cut. The weight has a movable cover for the purpose of putting in more or less weight, as the heft of the geer being cut may require.

To the extreme left of the upper part of the frame, Fig. 1986, is a thumb-nut for tightening up the spindle in case it should wear and become loose.

H, pulley over which the cord passes to support the weight P, used in cutting spiral geers.

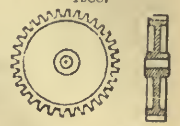
GEERING is the general term employed to denote a combination of mechanical organs, interposed between the prime mover and the working parts of machinery. Frequently, however, the signification is restricted to the series of toothed wheels by which the motion is conducted from one revolving axis to another, independently of the shafts and bearings by which they are supported. Two toothed wheels are also said to *geer* when they have their teeth engaged together, and to be *out of geer* when separate and consequently out of action.

In the transfer of motion from one axis to another in a system of mechanism, wheels are the most important organs. Of these there are two principal varieties with several modifications, distinguished by peculiarities of form, construction, and adaptation.

When motion is to be transferred from one axis to another which is parallel to it, the peripheries of the wheels act upon each other tangentially, and the teeth are disposed round their cylindrical surfaces in the direction of radii from their centres. Wheels of this sort take the general name of *spur geer*. In

the ordinary cast-iron wheels, the teeth are made in one piece, with the *rim;* and commonly the wheel consists of one entire piece, though sometimes the wheel is cast in segments when of very large size, and especially if intended for shipment, for convenience of packing and transport. Cast-iron wheels of all sizes above, and frequently below 18 inches diameter, are made with arms; but in very small-sized wheels the arms are commonly omitted, and the rim and teeth are united to the central boss by a thin continuous plate, as represented in elevation and section, by the annexed cuts. Wheels of this sort are usually denominated *plate-wheels,* to distinguish them from those of similar size having arms, and which are therefore described, especially by clock-makers, as being *crossed out.* In very small machinery the wheels are sometimes formed out of plain disks by cutting out a series of equidistant notches round the circumference.

1988.



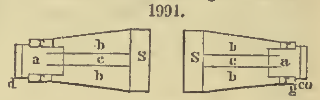
In wooden wheels, which were in general use for all species of millwork till towards the end of the last century, and of which we have still some examples, the teeth are formed of separate pieces, and fixed into equidistant mortises pierced through the rim of the wheel. The rim is formed of segments of hard wood firmly bound together by iron straps and bolts, and is connected to the shaft by a wooden framing, consisting of bars set at right angles. The square opening, thus left at the centre to receive the shaft, also of wood, and square at that part, is purposely made larger than the section of the shaft, to admit of adjustment and fixing by wedges. The arms are, however, very frequently mortised into the shaft; but such a mode of fixing weakens the shaft, and at the same time renders it difficult to get the wheel off, should this be required in consequence of the failure of the shaft.

Wheels of this kind are technically known as *cog-wheels,* and the teeth take the name of *cogs.* These are made of some well-seasoned hard wood, as mountain-beech, plane-tree, hornbeam, hickory, and the like, with the grain disposed in the direction of their length, which being the radical direction, is the most favorable to transverse strength.

A modification of this construction of toothed wheels is still very commonly employed in millwork under the name of *mortise-wheels.* In these, the body of the wheel is of cast-iron, and the teeth of wood, fixed into mortises made in the rim, as in the old cog-wheel. The individual teeth, or cogs, are often formed so that the part which projects without the rim is the tooth; and the shank, tail, or tenon, is made to fit its mortise in the rim of the wheel very tightly, and is left sufficiently long to project on the inside, so that being driven into the mortise up to the shoulders, it is secured in its place by an iron pin inserted into a hole bored through the tenon, closely under the rim of the wheel.

There is, however, another mode of fixing the cogs, which is more commonly practised than that described. This mode will be understood by reference to Fig. 1990, from which it will be observed that the cogs, instead of being made fast in their places by pins, are retained in the mortises of the rim by dovetail keys *v v*, driven between every contiguous pair inside of the rim. The tenons, when the cogs are intended to be fitted in this manner, are made with an expanding dovetail at their extremities, to receive one side of the key, which being driven tightly into the V-shaped space, thus formed between the ends of each pair inside of the rim of the wheel, retains the cogs in their places. The keys, which are made of well-seasoned hard wood, usually of the same kind as that used for the cogs, are made long enough to project some way beyond the side of the rim, to allow of their being driven in more tightly, should the cogs in the course of working become loose. The ends of the tenons are also very commonly made *flush* with the surface of the keys, but the mode of finishing shown in Fig. 1991 has some advantage in point of strength.

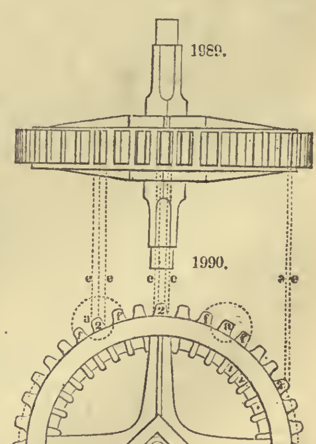
1991.



Spur mortise-wheel.—Figs. 1989 and 1990 give two views in elevation, and Fig. 1991 a section of a mortise spur-wheel of 34¼ inches diameter, and containing 48 cogs; pitch 2¼ inches.

Fig. 1991 is a section of the wheel where *a a* represents the cogs; *r r* the ring; *c c* the face arms; *b b* the feathers of the arms, and S S the socket or eye of the wheel.

Fig. 1989 is a view parallel to the axis of the wheel, and Fig. 1990 is a plan of the same wheel in the line of its centre.



1989.

1990.

These figures are intended to illustrate the mode of drawing the wheel. The pitch and number of cogs being given, the first part of this operation is to determine the diameter of the pitch circle. This may be done by multiplying the pitch of the teeth by their number, and dividing the product by 3·1416; or it may be directly found from the rule and table given in page 795; or the compasses may be at once set to draw the pitch circle from scale of Fig. 2022, (see pages 799 and 800.) The pitch being 2¼ inches, the radius of the pitch circle will be found in the line which runs parallel with A D, and which is marked 2¼; and the distance C to 48 in that line being the radius for a 2¼ inch pitch with 48 teeth, one point of the compasses placed in the intersection of the line 2¼ by C B, and the other in the intersection of the line terminating in 48, will be that radius. The other required dimensions will also be found in the line 2¼; the distance A C = the pitch; *a c* = the length; *b c* = the thickness; *a c* = the length from the pitch line to the point, and twice this is the working depth; the width of space is A *b*, and their lateral clearance is A *b* — C *b*, and the bottom clearance *a* C — 2 *a c*.

The same scale may be used in finding the proportions of parts in making out reduced drawings of wheels to different scales. If the compasses be set to the required pitch, and moved up the line C B, keeping one point in C B until the other point meets the line A B, the points running parallel to A C,

then in a line drawn parallel to A D, and passing through the points in which the compasses meet the converging lines, will be found all the other required dimensions in accordance with that scale.

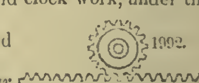
Fig. 1989 shows the method of finding the shape and position of the teeth, by the application of the T square to Fig. 1990, as indicated by the dotted lines *e c e e* at 2, 2, 2. The lines forming the outline of the shaft are found in a similar manner from Fig. 1990.

The mode of drawing the curves of the top and bottom of the teeth is shown by the dotted circles, marked *f f f f*, and which are drawn from the centres of the teeth *a a*. This curve is, however, very variable, and depends much upon the size of the pinion intended to work in the wheel.

The mortise-wheel is preferred, where a high velocity with smoothness of motion is required. It is usually made to work into a wheel with cast-iron teeth, a pair of this sort being found to work together with less vibration, less noise, and less wear, than when both wheels of the pair have iron teeth. For these reasons it is very common, in good millwork, to make one wheel of every large-sized pair with wooden cogs, especially when the speed is high, and subject to variations of velocity. But it may be here remarked, that in cases where a very large wheel is required to geer with a smaller one, the former is commonly made the mortise-wheel.

It may be here well to observe, that when two wheels geer together, the one which communicates the motion to the other is called the *driver* or *leader;* and the wheel impelled is the *follower*. If the two wheels be of very different sizes, the smaller one very commonly takes the name of *pinion*, which may be regarded as the diminutive of *toothed-wheel*. For the sake of further distinction the teeth of pinions are often termed *leaves*. In geering of the ordinary kinds, the pinions are commonly of the same form of construction as the wheels with which they act; but in the old wooden machinery the pinion is commonly formed by inserting the extremities of a number of wooden cylinders into equidistant holes, in two parallel disks, (technically called *heads* and *cheeks*,) upon a square shaft. A pinion of this description is denominated a *trundle*, *lantern*, or *wallower*, and its cylindrical teeth are termed *staves*, sometimes *rounds* and *roundles*, very commonly pronounced *rungs*.

In early machinery the toothed wheels were often cut out of thin metal plates, which rendered it impossible to make a pair thus formed to work together, for the slightest deviation of one of the wheels from the plane of rotation of the pair, would allow the teeth to lose hold of each other sidewise. To obviate this, one of the wheels of a pair was always made either in the lantern form, as just described, or more commonly with pins inserted at one end only, into a disk. A modification of this method also in use, was to form the teeth on the edge of a hoop; by these arrangements, the thin wheel was enabled to retain its hold of the teeth of the wheel with which it geered, notwithstanding a little deviation from the plane of rotation. This form of wheel is still in common use in watch and clock work, under the names of *crown* and *contrate wheel*.



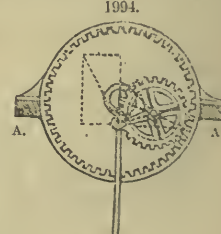
1992.

Fig. 1992 represents the case of a wheel working into a *rack*, commonly called a rack and pinion.

If the rack be curved upon the pinion it becomes an *internal* or *annular* wheel, that is, a wheel, having the teeth inside of the rim, as represented by Fig. 1993. In this the axes of the wheel and pinion are parallel, and moreover, revolve in the same direction. The arms of the internal wheel are necessarily situated behind the rim to prevent their interference with the pinion, and the latter must overhang its bearing, that is, be fixed on the extremity of its shaft, to avoid interference with the arms of the wheel.

1993.

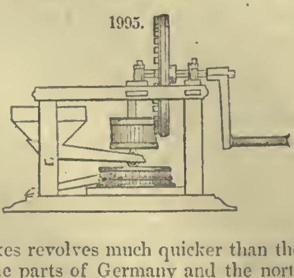
1994.



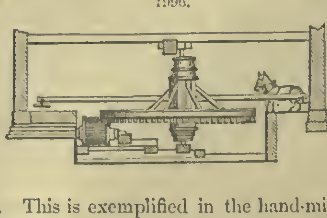
When the pinion is made half the diameter, that is, equal in diameter to the radius of the annular wheel, the arrangement admits, in small steam-engines, of an application, known as White's parallel motion. In this the annular wheel is fixed, and the pinion is attached upon a crank-arm. The rod being attached at the circumference of revolution of the pinion, it is thereby made to describe a right line, coinciding with a diameter of the annular wheel, which is therefore equal to the length of the stroke of the engine.

Similar combinations to that of the crown-wheel and pinion were early introduced into mechanism. In examples of this construction, which are still to be found along with cog-wheels and trundles, the cogs are simply disposed on the rim of the wheel, from which they project in lines parallel to the axis, so as to geer with those of an ordinary cog-wheel, having the cogs disposed round the circumference, or with a trundle when

1995.



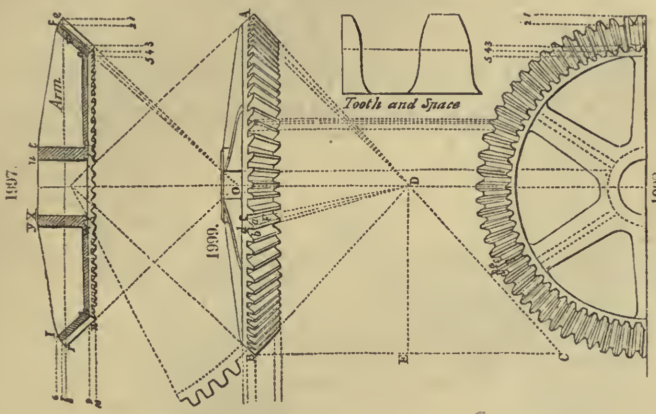
1996.



one of the axes revolves much quicker than the other. This is exemplified in the hand-mill still to be found in some parts of Germany and the north of Europe, as depicted in Fig. 1995, in which we have the *face-wheel* upon the crank-axle, geering with the trundle upon the millstone axle, which forms an angle of 90° with the former.

In several parts of Scotland, the combination shown in Fig. 1996, as a first pair in the geering of a thrashing-mill, is still common.

In spur-geer, the principle depends upon two cylindrical surfaces being made to act on each other tangentially; in bevel-geer the cylinders are replaced by thin frusta of cones, which have their smooth surfaces exchanged for a regular series of equidistant teeth directed to the apex of the cone; so that a right line passing through the apex, if brought into contact with any part of the side, or top of a tooth, shall touch it throughout its whole breadth; consequently in any pair adapted to work together, the apices of their cones must meet in the same point, and thus the contact of one tooth with another will take place along their sides. This is illustrated in Figs. 1997, 1998, and 1999.



Detailed drawings of a mitre-wheel. Fig. 1997 is a section, Fig. 1998 a side view, and Fig. 1999 a face view of a mitre-wheel. This is a kind of bevel-wheel that is used when it is required to change the direction of motion 90° without altering its angular velocity—a case which occurs very frequently in practice. It is obvious that only one pattern is required for the pair of wheels of this kind, and the method of drawing any one of them will apply to both. The following is the process:

Draw a line A B equal to the diameter of the wheel, (diameter of pitch circle;) bisect A B, and produce a line at right angles to it, which will represent the centre line of the shaft. The points C and D in this line, Figs. 1997 and 1998, where the produced centre lines of the two shafts intersect each other, is the point to which all the lines running in the direction of the breadth of the teeth are drawn. The distance of the point D or O from the line A B is equal to half the diameter of the pitch circle. This will be evident if B C be drawn from the point B at right angles to A B: the line B C being equal to A B, will represent the proper position of the other wheel, and if bisected in E, the line E D produced perpendicular to it will be the centre line of the shaft. The point D is therefore the position of the common apex of the two cones.

Join A D and B D, and A O and B O, and at right angles to these lines draw *e m* and *r i*, Fig. 1997, passing through the points A and B. Make A *k*, B *n* equal to the breadth of the teeth, and draw *k g* and *n h* parallel to A *m*, B I. Set off upon A *m*, B I the length of the teeth, as *e f*, *r s*; also the thickness of rim, as *f m*, *s* I; and from these points let lines be drawn to the apex of the cones, as shown. Join *g h*, and make *q v* equal to the size of the eye; P *q* and V *w* are each to be equal to the intended thickness of the eye, and P *t* equal to the depth. Draw *p t*, *q u*, *v x*, *w y*, at right angles to *g h* and join *t m* and *y* I, and thus a section of the wheel is determined, from which all the lines and points requisite for drawing the plan can be found.

Fig. 1998 is a face view, the mode of proceeding with which is to transfer the points 1, 2, 3, 4, 5, from Fig. 1997 to it, by means of the T square, which determines the extremities of the teeth and rim; circles are then described passing through these points, and that passing through the point 4 is divided into the number of teeth intended to be in the wheel: the thickness of the teeth is then set off, and drawn in a similar manner to that described in Fig. 1990. The lines forming the edges of the top and bottom of the teeth are radial lines, and of course are drawn in the direction of the centre of the wheel.

Fig. 1999 the side view. The elementary lines for this drawing, viz. 6, 7, 8, 9, 10, correspond to the lines in the section having the same figures, and the points forming the teeth are derived from Fig. 1998, by the application of the square. For example, the two points *a b*, forming the top of the outside of the tooth F, are transferred to the line marked 8, on Fig. 1999, and the points *c d* to the line marked 7; these points being connected by the lines *a c* and *b d*, form the end of the tooth: straight lines are then drawn from *a b* in the direction of the point D, until they meet the line marked 10, and a line in the same direction from *c* meeting the line marked 9. The terminations of these lines mark out the extremities of the inside of the tooth, which being joined, complete the tooth F. The shape and direction of the other teeth in the wheel are found by a similar operation to that used for finding F, keeping in view that the slope of all the teeth tends to the point D.

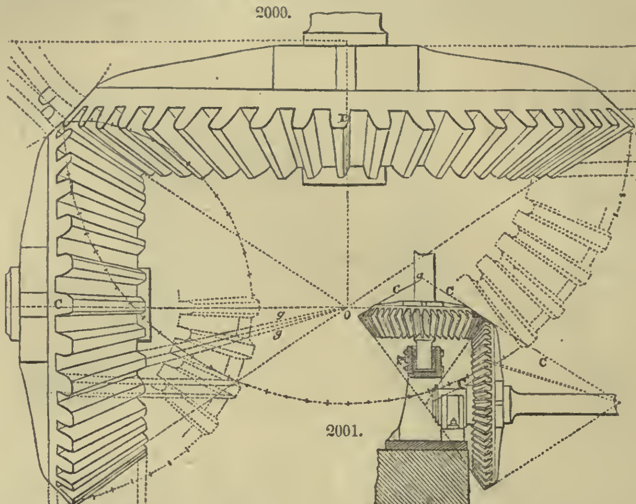
The eye of this wheel is intended for a round boss, on which it may be keyed in the usual manner. The thickness of the web is equal to that of a tooth of the wheel; the arms have a thickness somewhat less, and the thickness of the metal of the eye is equal to the pitch of the teeth.

The radius representing the circle of action of wheels of the kind described, is found by producing the line B I till it meets the centre line of the shaft.

Bevel-wheel and pinion.—This pair of wheels, shown in Fig. 2000, differs from that in the preceding in being of unequal size; and hence come under the denomination of *bevel-wheels.* Both wheels of this pair are supposed to be placed on horizontal shafts, in which they differ from the pair of bevels in Fig 2001, of which the pinion is placed on an upright or vertical shaft, having its bottom bearing in a foot step, while the wheel with which it is in geer is placed on a horizontal shaft. The mode of drawing a pair of wheels of this kind will be understood from what follows.

Fig. 2000 is a side view of the wheel and pinion.

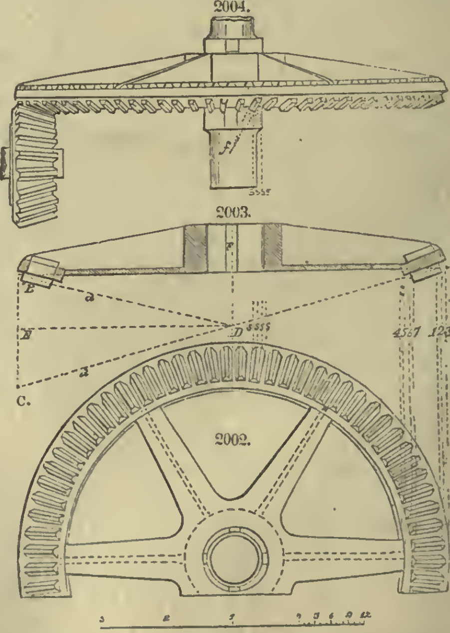
2000.



When only the side view of a bevel-wheel and pinion is required, it is not necessary that the whole section, as in Fig. 1997, should be drawn, farther than to determine the position of lines *a b c d e* and *f*, and the position of the apex of the two cones, as at O, Fig. 1997. It should also be observed, in the example given in Fig. 1997, that the view in Fig. 1998 was requisite for drawing the side view, only so far as finding the position of the four points of the teeth *a b c d* was concerned; but for common purposes, these points can be found with sufficient exactness by merely drawing circles of the same diameter as the wheel and pinion, and dividing them into the given number of teeth, and marking off their thickness. This will be readily understood, by examining Fig. 2000, in which circles, so divided, are laid down equal in diameter to the wheel and pinion; and 6, 7, 8, &c., show the thickness of the teeth. Now by applying the T square, as at 6 and 7,* and marking these points upon the pitch line *c*, the lines forming the sides of the teeth at 3, 4, are found by drawing them parallel to the centre line, which is drawn to the point where the lines 1 and 2, forming the bevel of the ends of the teeth, meet. This point is not shown in the drawing, being at too great a distance for the size of the plate. The lines forming the face of the teeth are all drawn to the point O where the cones meet, as shown by the lines *g g*; and exactly the same mode is adopted in determining the shape and position of the teeth of the pinion C.

When the wheels are drawn to a small scale, as in Fig. 2001, the two lines forming the sides of the teeth may both be drawn to the same point, as shown at *a*, as in such cases they will not differ sensibly from the parallel.

2004.



A bevelled mortise-wheel.—Figs. 2002, 2003, and 2004, are plan, section, and side view of a bevel-wheel, having wooden teeth, commonly termed cogs. The ratio which the wheel and pinion bear to each other is four to one, as will be observed from the section, Fig. 2003, in which A B

* The scale is too small in the cut to show these figures. but the process will readily be followed by a glance at the method pursued in Fig. 1997.

represent the diameter of the wheel, and B C that of the pinion. By following the instructions given in Figs. 1997, 1998, and 1999, the point D will be found to be the junction of the two cones, and consequently that point to which all the lines of the teeth are drawn.

The manner of finding the points for drawing the plan, Fig. 2002, is by applying the square to Fig 2003, as shown by the dotted lines 1, 2, 3, 4, 5, 6, 7, &c., and the shape of tooth in Fig. 2004, is precisely the same as described in Fig. 1999.

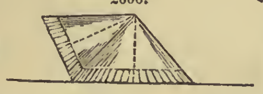
In these examples, motion is led off at an angle of 90°; but bevel-geer may be employed to change the direction of the motion to any angle required. This will readily appear from the following diagrams, in which, for the sake of simplicity, we suppose the cones continued till their apices meet.

In Fig. 2005 we have an illustration of the principle of those cases already described. Here *a* is the point at which the apices meet, and supposing the motion to be conveyed in the axis A *a*, it is transferred to the axis *a* B in a right angle to its first direction.

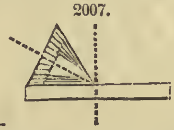
In Fig. 2006 the change of direction is no longer a right angle; for the angle included between the axes is obviously less than 90°, and might evidently be made still less by diminishing the angles which the slanting sides of the cones make with their respective axes. Wheels of this kind—rather wheels of which the angle included by the axes is *less* or *greater* than a right angle—are usually distinguished by the name of *conical-wheels.*

2005.

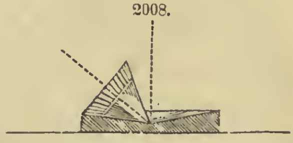
2006.



2007.



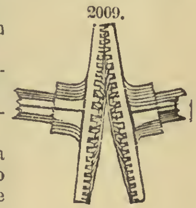
2008.



In Fig. 2007 the apices of the two cones meet in a point, so that one of them becomes a plane surface; its teeth therefore become radial as referred to its apex; in other words, they diverge in the manner of radii, drawn from the centre *a*. The change in the direction of the motion is in this case greater than 90°, and might be further increased, if consistent with the relative velocity of the pair, by increasing the angle of the cone.

In Fig. 2008 we have an expression of a mode of changing the angle of direction differing from those shown in the preceding figures, inasmuch as one of the cones has become hollow, and the teeth are disposed upon its interior surface, thereby forming an internal bevel-wheel analogous to the internal spur-geer previously noticed; wheels are, however, very rarely made in this manner.

2009.



When the direction approaches a right line, the cones may be made to roll upon each other, as in Fig. 2009.

In cases where the axes do not meet in a point as hitherto considered, the geering becomes somewhat more complicated.

The direct mode of arrangement in this case is to employ an intermediate double bevel-wheel.

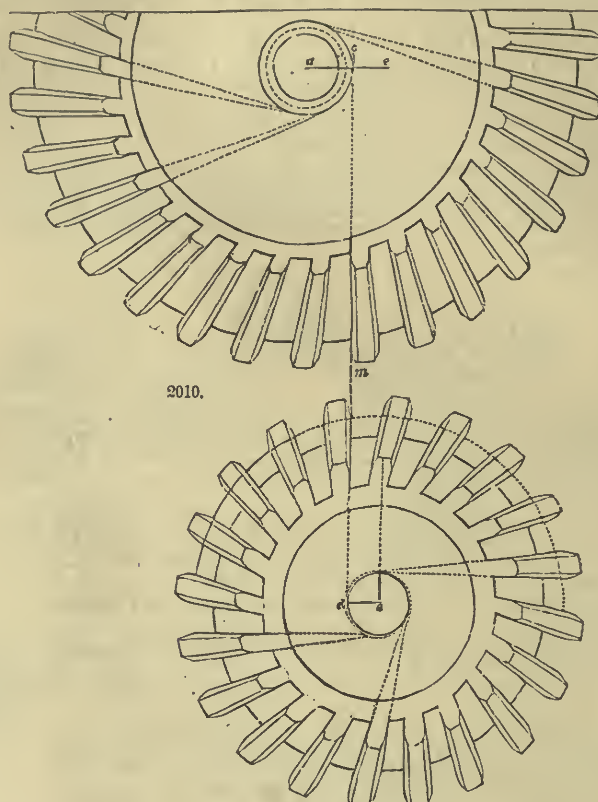
To avoid the multiplication of parts, the object is more commonly attained by a modification in the direction of the teeth, by which they are made to come into contact in an oblique position, answering to the obliquity of the position of the cones upon which they are formed. This artifice is often practised when it is necessary to cross the two axes,—which it must be observed are not theoretical lines but actual shafts of diameters proportionate to the power they are required to transmit. This arrangement is represented by Fig. 2010, and illustrates that variety of toothed-geer, known as *skew-wheels.* Wheels of this character are commonly avoided in practice; as, on account of the oblique form of the teeth, they are not only of more difficult construction, and therefore rarely possess the same degree of accuracy which we find in bevels of the ordinary sort, but the strain upon the shafts is likewise oblique, and therefore more severe upon the bearings.

Another form of toothed-wheel, known as "Hooke's Geering," from the name of the inventor, Dr. Hooke, consists in disposing the teeth upon the peripheries of the wheels in equidistant steps, or in such a manner as to form a continuous slope. This remarkable contrivance, which has several times since been re-invented and patented, was intended, to use the words of the learned inventor, "First, to make a piece of wheel-work so that both the wheel and pinion, though of never so small a size, shall have as great a number of teeth as shall be desired, and yet neither weaken the work nor make the teeth so small as not to be practicable by any ordinary workman. Next, that the motion shall be so equally communicated from the wheel to the pinion, that the work being well made, there can be no inequality of force or motion communicated. Thirdly, that the point of touching and bearing shall be always in the line that joins the two centres together. Fourthly, that it shall have no manner of rubbing, nor be more difficult to be made than the common way of wheel-work, save only that workmen have not been accustomed to make it."

The mode of construction contemplated by Dr. Hooke was to make the wheel and pinion of several plates, laid one beside the other, and to bolt them together. These plates are individually cut into wheels, which are fitted together in the manner described, but in such order that the teeth of the successive plates follow each other in regular gradation, so that the last tooth of each group may, within one step, answer to the first tooth of the next group. The pinion being constructed in the same manner, and of the same number and thickness of plates, it is obvious that the inequalities in the touching surfaces are reduced in proportion to the number of thicknesses; and the amount of rubbing friction is reduced to what it would be between the two next teeth of one of the sets.

This is still further reduced by reducing the steps formed by the ends of the teeth to a straight, or rather a spiral edge. A wheel and pinion of this kind, observes Dr. Hooke, are equivalent to the same having an infinite number of teeth, and are best made each of a single plate of convenient thickness,

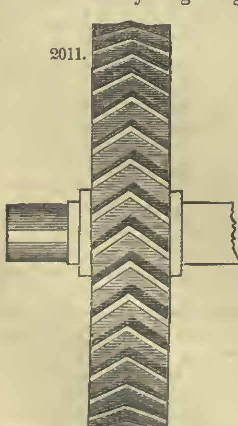
"which thickness must be more or less, according to the bigness of the sloped tooth. And this is always to be observed in the cutting of the teeth, that the end of one sloped tooth on the one side be full as forward as the beginning of the next tooth on the other side;" in other words, that the end *b* of one tooth on the right side be full as low as *c*, the beginning of the next tooth on the left side.



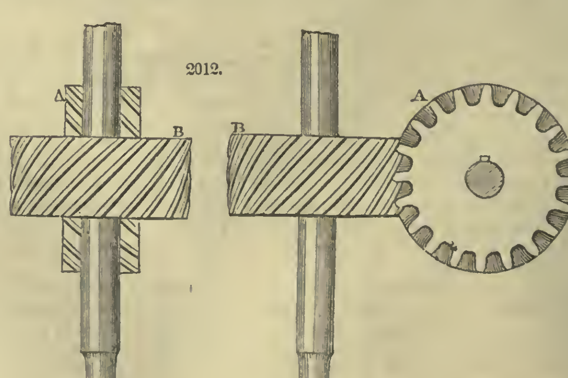
2010.

In a pair of wheels of this construction it is easy to perceive that the contact of the teeth will bear every instant at a single point, which, as the wheels revolve, will travel from one side to the other, a fresh contact always beginning on the first side immediately before the last contact has ceased on the opposite side. The contact, moreover, being always in the plane of the centres of the pair, the action is reduced to that of rolling; and as there is no sliding motion, there is consequently no rubbing friction between the teeth.

2011.



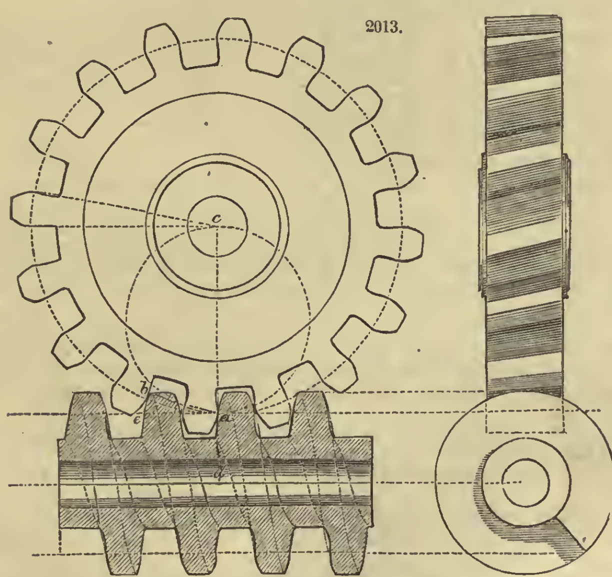
2012.



The motion of wheel work of this description is remarkably smooth and free of vibration, but is liable to the objection of introducing endlong pressure upon the axes, in consequence of the obliquity of the surfaces of contact to the planes of rotation. To obviate this objection, the wheels have been made with double sloped teeth, in the form represented in Fig. 2011. This wheel may be conceived to be composed of two thicknesses of metal, each having teeth formed upon its periphery in the same manner as the wheel of Dr. Hooke just described, and that these plates are fitted together with the direction of the teeth reverse to each other. More strictly, the wheel may be supposed to consist of two equal and concentric plates, which being, in the first place, made as separate wheels, have their teeth of equal size, and cut at equal but contrary angles with the axis of rotation, are fitted together so that the teeth of the one plate meet those of the other plate in the plane of contact. The slopes of the teeth on the two sides being thus reverse, and projected at equal but contrary angles with the axis of the wheel, and the pinion being formed in the same manner, the action of the respective sides of the V-shaped teeth on each other will be as before described; but the endlong pressure arising from the obliquity of contact on one side, will be exactly equal and opposite to that resulting from the obliquity of action on the contrary side; these pressures must, therefore, neutralize each other, and relieve the journals of an amount of friction which is necessarily involved in the mode of action contemplated in the original invention.

A further modification of Dr. Hooke's geering has of late been somewhat extensively adopted, especially in the newer cotton-spinning machines. This consists, when the direction of the motion is simply to be changed to an angle of 90°, in forming the teeth upon the periphery of the pair at an angle of 45° to the respective axes of the wheels; it will then be perceived that if the sloped teeth be presented to each other, in such a way as to have exactly the same horizontal angle, the wheels will geer together, and motion being communicated to one axis, the same will be transmitted to the other at a right angle to it, as in a common bevel pair. Thus, if the wheel A, Fig. 2012, upon a horizontal shaft have the teeth formed upon its circumference with an angle of 45° to the plane of the axis, it can geer with a similar wheel B upon a vertical axis. Let it be upon the driving-shaft; then the motion transmitted will be changed in its direction, as if A and B were a pair of bevels of the ordinary kind, and as with bevels generally, the direction of motion will be changed through an angle equal to the sum of the angles which the teeth of the wheels of the pair form with their respective axes.

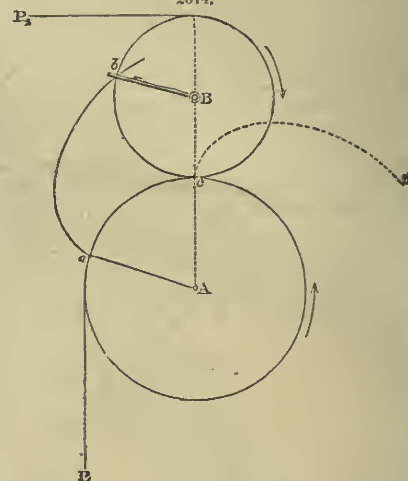
2013.



The contrivance, as stated, is directly a modification of Dr. Hooke's geering; but, in effect, it may be described as a modification of the tangent screw and screw-wheel. In this last arrangement, represented by Fig. 2013, in its common form, it will be observed that the plane of the thread coinciding so nearly with that of the axis of the wheel, renders it necessary that the screw be uniformly the driver; and as the screw, by one revolution, passes only a single tooth of the wheel, the motion is necessarily slow. Both of these circumstances are manifest advantages in a large class of instances; but for very many purposes it is desirable to retain the principle of the screw, with an increase of velocity and a diminution of its rubbing friction. This is accomplished by diminishing the inclination of the thread of the screw to the axis—more correctly by increasing the number of separate spiral threads upon the surface of its cylinder; for, as every one of those spirals will pass its own wheel-tooth across the line of centres in a revolution of the screw, it follows that as many teeth of the wheel will pass that line during one revolution of the screw as this last has threads. If, therefore, we suppose the number of threads to be increased until they equal in number the teeth of the wheel, then the screw and wheel may be made exactly alike. This is precisely the case exemplified by Fig. 2012, in which we suppose A and B to be the same size, and to have the same number of spiral teeth—which might manifestly be continued round the axes of the wheels without affecting in the least their mode of action.

Relative direction and velocity of rotation.—A wheel describes a circle because its axis is fixed; but the direction and the velocity of its rotation depend upon its connection with the next wheel of the train, which lies between it and the moving power; and it is evident that the relative velocities of any given pair, must depend upon the relative magnitudes of the circles which they respectively describe. Thus, supposing the circumference of the wheel be double that of its pinion, and, therefore, to have double the number of teeth upon it, every revolution of the wheel must of necessity effect two revolutions of the pinion about *its* axis. And similarly knowing the respective circumferences of any pair acting together, it is easy to assign the ratio of their velocities. This form of the question, however, more rarely comes into use than that requiring the determination of those quantities from the diameters, which is slightly more involved, and renders it necessary, before entering further upon the consideration of the subject, to examine the conditions a little more closely.

2014.



Supposing that A and B, Fig. 2014, are two axes of motion referred to the same perpendicular plane, and that A B is a right line connecting them. Further, let it be supposed that the moving force is transmitted through A, and that it is required to connect it with B in such a way—that is, by a pair of spur-wheels of such sizes—that while A makes two revolutions B shall make three revolutions, the distance between A and B being six feet.

It is manifest that the circumferences of the wheels, the axes being fixed and the circumferences in *geer*, must of necessity have the same velocity. Thus, supposing for an instant that the question is already resolved, and that the circles described about A and B, having their point of contact at *c*, then if a constant force, P_1, act tangentially to the circle described about A with the radius A *c*, it is evident that the rotation of this circle being transmitted to that described about B with the radius B *c*, will cause it to describe an equal *length* of arc to that through which itself passes, in any unit of time. But although the arcs be of the same absolute length, it is easy to perceive that they form very different portions of their respective circles. In fact the arcs described by the two points of *a* and *b*, taken as portions of the circle to which they belong, are in the inverse ratio of the radii A *c* and B *c* by which the circles are described.

Now, if this be true for a part of a revolution, it is equally true for a whole revolution of either of the wheels, and consequently for any number of revolutions. Hence, to obtain the radii of the wheels, it only remains to divide the distance between the centres—that is, the line A B into parts inversely proportional to the number of revolutions which the wheels respectively make in the same unit of time. These rules are expressed as follows:—

I. To find the radius of the wheel, the relative number of revolutions and the distance between the centres of the pairs being given, multiply the distance between the centres by the numbers expressing the velocity of the pinion, and divide the product by the sum of the numbers expressing the relative velocities of the pair—understanding by velocities the number of revolutions which the wheels make in the same time.

II. To find the radius of the pinion or other wheel, multiply the distance between the centres by the number expressing the velocity of the wheel, and divide the result by the sum of the velocities; or subtract the radius of the wheel from the distance between the centres: the remainder is manifestly the radius of the pinion.

Now in the arithmetical question proposed, the distance *d* between the centres is six feet, the velocity of the wheel two, and that of the pinion three; hence,

$$\frac{6 \text{ feet} \times 3}{2+3} = \frac{18 \text{ feet}}{5} = 3 \text{ feet } 7\tfrac{1}{5} \text{ inches.}$$

$$\frac{6 \text{ feet} \times 2}{2+3} = \frac{12 \text{ feet}}{5} = 2 \text{ feet } 4\tfrac{4}{5} \text{ inches.}$$

$$\text{Sum of radii } d = R + r = 6 \text{ feet.}$$

Having the radii or diameters of the wheels given, it is not necessary to find their circumferences in order to determine the ratio of the velocities of their axes. The relative number of revolutions which they will make in a given unit of time is ascertained by dividing the measure of the one by that of the other, the quotient being the *number of revolutions, or parts of a revolution, the axis of that wheel will make which is made the divisor, while the axis of the wheel whose diameter or radius is divided makes one revolution.*

Questions of this kind may be solved very readily by means of the compasses and a scale of equal parts. Thus let A and B, Fig. 2014, be the given centres, the ratio of their velocities being respectively *two* and *three*, if the line joining the centres A and B be divided into $2+3=5$ equal parts, that is, into as many equal parts as there are units in the terms of the given ratio, the radius of the wheel upon A will contain three of these parts, and the radius of the pinion on B will contain the remaining two parts,

and the point of contact of the wheels will be at c. This method is very convenient in practice when the terms of the ratios are small.

In the preceding examples, only a single pair has been taken; but it frequently occurs in practice that motion is to be transferred through a system of shafts, with varying degrees of intensity, according to the purposes to be attained. It likewise not unfrequently happens that a pair of shafts are to be connected at such distances as to require the interposition of *carrier* wheels, that is, wheels intended simply to connect the two, without being subservient to any other purpose.

Let there be two motion-axes, A and B, of which the angular velocities are as 27 to 343, and let it be required to connect them by four wheels on two intermediate shafts, the wheels to have a common velocity ratio throughout. Let A be the driver; then the intensity of the motion is required to increase from 27 towards B, in which it is expressed by 343.

Now, it has been shown that if a pair of wheels be in geer, their radii are to each other as the angular velocities, that is, the relative number of revolutions which they make upon their axes. In order, therefore, that the geering pairs in the question proposed may have a common velocity ratio, it is obvious that the same must apply to the axes upon which they are fixed. These velocities ought, therefore, to form a geometrical progression, of which the first and last terms, ($A = 27$ and $B = 343$,) and also the number of terms, namely, the four axes, are given. Now, the formula for all such questions, m being the number of geometrical means to be inserted, ρ the ratio, is for an increasing series.

$$\rho = \sqrt[m+1]{\frac{B}{A}} \text{ which becomes } \rho = \sqrt[3]{\frac{343}{27}} = \frac{7}{3}$$

$$\text{Hence the angular velocity of } C = 27 \times \frac{7}{3} = 63$$

$$\ldots\ldots\ldots\ldots\ldots\ldots \text{ of } D = 63 \times \frac{7}{3} = 147$$

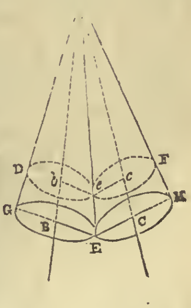
Also, A will be connected with C, and C with D, and D with B by wheels of radii 7 and 3 respectively.

These examples illustrate the whole process of calculation of the transfer of angular velocity from one axis to another, and include every case of the kind to be met with in practice.

In the case taken, we have supposed the motions of the pair to be in the same plane, and the axes of rotation of the circles parallel. But it is often found necessary to change the direction of motion through all conceivable angles, as in case the axes of rotation meet in a point by common bevels and face wheels, and when the axes are neither parallel nor do they meet in direction by screw-wheels. These cases require to be separately noticed.

Let us, in the first place, suppose that the two axes of rotation B A and C A intersect in A, and include the angle B A C. If we suppose a cone to be generated by the revolution of the line A E about A B, and another by the revolution of the line A E about A C, then these cones being made to revolve *in contact* about their respective axes A B and A C, their surfaces will *roll* upon one another along their whole length of contact A E. For, as already shown, if n times the circumference of a circle D e be equal to m times that of a circle F e, and these circles be conceived to revolve in contact about their centres b and c, and to carry the cones with them, then it is evident that whilst the cone E A G makes n revolutions the cone E A H will make m revolutions. But n times the circumference of any other circle E G of the one cone, is equal to m times the circumference of the corresponding circle E H of the other cone; for the diameters of these circles, and, therefore, their circumferences are to one another in the same proportion as the diameters and circumferences of the circles e D and e F. It is therefore obvious, that whilst the cones make n and m revolutions respectively, the circles E G and E H are carried through n and m revolutions respectively, and that n times the circumference of E G being equal to m times the circumference of E H, it follows that these circles *roll* in contact through the whole of their path. And the same is equally true of any other corresponding circles in the cones, and therefore of their whole surfaces, so that the rotation of one axis being communicated to the other, by the rolling together of the two cones, the surface of the one cone will carry with it the surface of the other along the whole line of contact A E with equal perimetral velocities, and with angular velocities inversely proportional to the circumferences, diameters, or radii, of the corresponding circles.

2015.

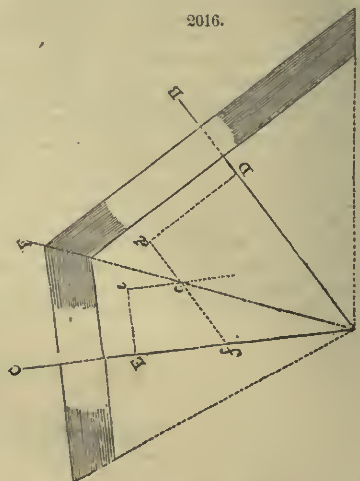


In practice, *thin* frusta only of the cones, with teeth upon *their* perimeters, are employed; but in this there is no new consideration involved, as respects the angular velocities of the axes upon which the wheels are carried. In determining the size of a pair of bevels, we are not, however, limited to any particular diameters as when the axes are parallel; the wheels may be made of any convenient sizes, and the teeth consequently of any breadth, according to the stress they are intended to bear.

The question, however, which presents itself here, is the mode of determining the *relative* sizes of the conical frusta of a pair; and this resolves itself into a division of the angle included between the two axes inversely as the ratio of their angular velocities. Let B and C be the position of the two given axes, and let them be prolonged till they meet in a point A. Further, let it be required that C make *seven* revolutions while B makes *four*. From any points D and E in the lines A B, A C, and perpendicular to them, draw D d and E e of lengths (from a scale of equal parts) inversely as the number of revolutions which the axes are severally required to make in the same unit of time. Thus, the angular velocity of axis B being 4, Fig. 2016, and that of the axis C being 7, the line D d must be drawn $= 7$, and the line E $e = 4$. Then through d and e parallel with the axes A B and A C draw $d e$ and $e c$ till they meet in

c. A straight line drawn from A through c will then make the required division of the angle B A C, and define the line of contact of the two cones, by means of which the two rolling frusta may be projected at any convenient distance from A.

Otherwise, having determined the relative perimeters, diameters, or radii, of the pair, then the lines D d and E e are to each other directly as these quantities.



2016.

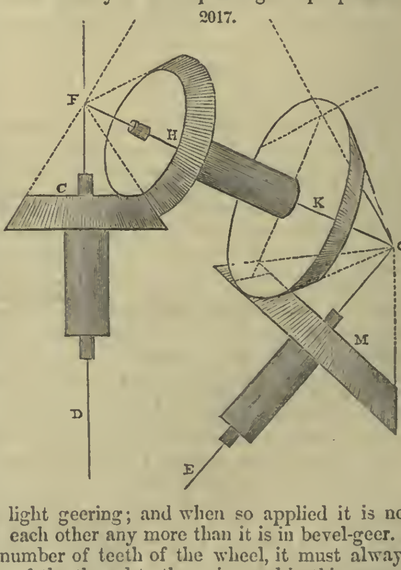
The point c may also be found more directly thus: From A towards C in the axis A C, set off from a scale as many equal parts (A f) as there are units in the number (7) expressing the velocity of that axis; from the point f draw f c parallel to A B, and set off from the same scale as many parts (f c) as there are units in the number (4) expressing the velocity of the axis A B; then a line drawn from A through c, as before, will divide the angle, as required.

By one or other of these methods the division of the angle of inclination of the axes may always be determined, the ratio of the angular velocities of the pair being known.

The case in which the axes are neither parallel nor intersecting, admits of solution by means of a pair of bevels upon an intermediate axis, so situated as to meet the others in any convenient points.

Thus, if D F and E G, Fig. 2017, be the two given axes, they may be connected by a third axis F G intersecting them in the points F and G; and if a shaft be mounted in the position of this third axis with a pair of bevels upon it, geering with the bevels on the main axes, and having their apices in the points F and G of these axes, the motion of the driving-shaft will be communicated, as if the two bevel-wheels C and M were in immediate contact; the ratio of their velocities remaining the same, provided the bevels H and K be of the same size. If it be required to bring up the speed or reduce it, between the two shafts, in a higher ratio than is convenient by that arrangement, the interposed bevels will afford additional facility of accomplishing the purpose.

2017.



When the contiguity of the shafts is such as to permit of their being connected by a single pair, skewed-bevels are frequently employed as shown in Fig. 2010; and as respects the relative velocities of a pair of this kind, it is evident that the same law obtains as in the preceding cases.

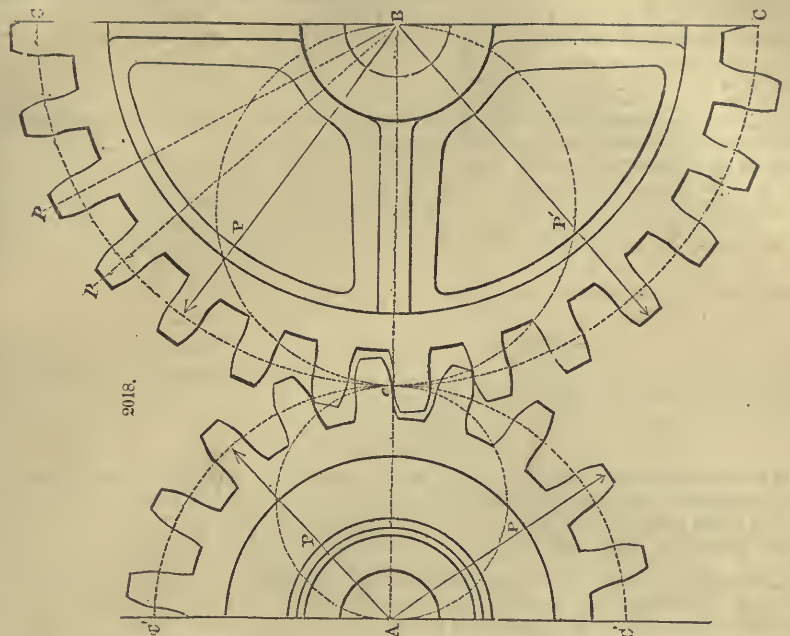
When the axes are at right angles to each other, and do not intersect, the wheel and screw may be employed to connect them. The velocity of angular motion is in this arrangement immediately deduced from that of the screw, its number of threads, and the number of teeth in its geering wheel. Thus, if it be required to transmit the motion of one shaft to another contiguous, and at right angles to it—the angular motions being as 20 to 1; then, if the screw be a single-threaded one, the wheel must have 20 teeth; but if double-threaded the number of teeth will be increased to 40, for 2 teeth will be passed at every revolution. If the velocities be as 2 to 1, the condition is, that the screw have half as many threads upon its barrel, as there are teeth on the wheel; and if 1 to 1, the wheel and screw lose their distinctive characters: both become many-threaded screws under the form of wheels, as represented by Fig. 2011. Wheels of this sort may often be applied with peculiar advantage, especially in light geering; and when so applied it is not essentially necessary that the axes be at right angles to each other any more than it is in bevel-geer.

If the screw have few threads compared with the number of teeth of the wheel, it must always assume the position of driver on account of the obliquity of the thread to the axis; and in this respect its action is analogous to that of a travelling rack, moving endwise one tooth, whilst the screw makes one revolution on its axis.

On the pitch of wheels.—The primary object aimed at in the construction of toothed-geer is the uniform transmission of the power, supposing that to be constant and equal. This implies that the one wheel ought to conduct the other, as if they simply touched in the plane, passing through both their centres. This plane is denoted by the line A B, in Fig. 2018.

When this line—which is usually denominated the *line of centres*—is divided into two parts, A c and B c, proportional to the number of teeth formed upon the perimeters of the pinion and wheel, these two parts are *proportional* or *primitive radii* of the pair; and a circle C C being described from each centre passing through the common point c, limits what is called the *pitch line* or *circle;* that is, a circle described from the centre A, and another from the centre B, through the same point, are called, the first, the *pitch circle* or *pitch line* of the pinion, and the other of the wheel. They are also sometimes called the *primitive* and *proportional* circles. If the pitch circle be divided into as many equal parts as there are teeth to be given to the wheel the length of one of these parts is termed the *pitch of the teeth.*

One of these arcs, as that intercepted by *p p* in Fig. 2018, comprehends a complete *tooth and space*, meaning by *space* the hollow opening between two contiguous teeth.



2018.

By the pitch lines of a geering pair is, therefore, to be understood the proportional circles in which they would revolve upon each other if they were simply cylinders without teeth; and the pitch of the teeth is the length of arc of the pitch circles, measured from the centre of one tooth to the centre of the contiguous one. Any right lines, P and P, drawn from the centre of the wheels till they meet the pitch circles or lines, are termed proportional radii, because they determine the relations of their angular velocities; and any similar radial lines, P′ and P′, continued to the extremities of the teeth, are called the *true radii* of the wheel and pinion—for no very obvious reason. In bevel and conical wheels the pitch circle is the base of the frustum, as A B of Fig. 1997.

Rules.—I. To find the pitch of the teeth of a wheel, the diameter and number of teeth being given, divide the diameter D, (in inches,) by the number of teeth N, and multiply the quotient by 3·1416: the product is the pitch in inches or parts of an inch.

II. To find the diameter of a wheel, the number of teeth and pitch being given, divide the pitch by 3·1416, and multiply the quotient by the number of teeth.

III. To find the number of teeth, the diameter and pitch being given, divide 3·1416 by the pitch, and multiply the result by the diameter in inches.

In ordinary geering the pitches most commonly in use range from 1 inch to 4 inches, increasing up to 2 inches by *eighths*, and beyond by *fourths* of an inch. Below inch, the pitches decrease by *eighths* down to ¼ inch.

The pitches being few and definite, the rules given above may be greatly simplified by the use of the annexed table, which will be found very convenient when the diameter D is to be determined, the pitch P and number of teeth N being given; and conversely, when the diameter and pitch are given to find the number of teeth.

The use of this table may be rendered obvious by the following examples:—

1. Given a wheel of 88 teeth, 2½-inch pitch, to find the diameter of the pitch circle. Here the tabular number in

Pitch in inches and parts of an inch.	$D = \frac{P}{\pi} \times N$ RULE.—To find the diameter in inches, multiply the number of teeth by the tabular number answering to the given pitch.	$N = \frac{\pi}{P} \times D$ RULE.—To find the number of teeth, multiply the given diameter in inches by the tabular number answering to the given pitch.
Values of P	Values of $\frac{P}{\pi}$	Values of $\frac{\pi}{P}$
6	1·9095	·5236
5	1·5915	·6283
4½	1·4270	·6981
4	1·2732	·7854
3½	1·1141	·8976
3	·9547	1·0472
2¾	·8754	1·1333
2½	·7958	1·2566
2¼	·7135	1·3963
2	·6366	1·5708
1⅞	·5937	1·6755
1¾	·5570	1·7952
1⅝	·5141	1·9264
1½	·4774	2·0944
1⅜	·4377	2·2848
1¼	·3979	2·5132
1⅛	·3568	2·7926
1	·3183	3·1416
⅞	·2785	3·5904
¾	·2387	4·1888
⅝	·1989	5·0266
½	·1592	6·2832
⅜	·1194	8·3776
¼	·0796	12·5664

the second column answering to the given pitch is ·7958, which, multiplied by 88, gives 70·03 for the diameter required.

2. Given a wheel 33 inches diameter, 1¾-inch pitch, to find the number of teeth. The corresponding factor is 1·7952, which multiplied by 33 gives 59·242 for the number of teeth, that is, 59¼ teeth nearly. Now, 59 would here be the nearest whole number; but as a wheel of 60 teeth may be preferred for convenience of calculation of speeds, we may adopt that number and find the diameter corresponding. The factor in the second column answering to 1¾ pitch is ·557, and this multiplied by 60 gives 33·4 inches as the diameter which the wheel ought to have.

A mode of sizing wheels in relation to their pitches, diameters, and numbers of teeth, is adopted in some engineering factories as a simplification of that explained above.

Suppose the diameter of the pitch circle to be divided into as many equal parts as there are teeth to be given to the wheel; let one of these parts be called the *diametral pitch*, to distinguish it from the *circular pitch* hitherto employed, and let a few definite values (in terms of the inch) be assigned to it; then it is clear, that calling M the diametral pitch, we have the relation $\frac{D}{N} = M$. And as M is always a simple fraction of an inch, let $M = \frac{1}{m}$, then we have the general expressions,

$$N = m \times D \qquad \frac{N}{D} = m \qquad D = \frac{N}{m}$$

To illustrate this by an arithmetical example, let it be assumed that a wheel of 20 inches diameter is required to have 40 teeth; then the diametral pitch,

$$M = \frac{D}{N} = \frac{20}{40} = \frac{1}{m} = \tfrac{1}{2} \text{ inch};$$

that is, the diameter being divided into equal parts corresponding in number to the number of teeth in the circumference of the wheel, the length of each of these parts is ½ an inch, consequently $m = 2$; and according to the phraseology of the workshop, the wheel is said to be one of *two pitch*. The circular pitch corresponding to this diametral pitch is by the properties of the circle $\frac{1}{2} \times 3{\cdot}1416 = 1{\cdot}5708$ inch.

In this mode of sizing wheels a few determined values are given to m, as 20, 16, 14, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, which includes a variety of pitches from ⅛ inch up to 3 inches, according to the following table, which shows the value of the circular pitches corresponding to the assigned values of m.

Values of m.	1	2	3	4	5	6	7	8	9	10	12	14	16	20
Corresponding circular pitch in decimals of an in.	3·142	1·571	1·047	·785	·628	·524	·449	·393	·349	·314	·262	·224	·196	·157

From this table, having the value of m given, the corresponding circular pitch is found; and from the rules given above, if the number of teeth and value of m be known the diameter of the wheel is also known, for $D = N \div m$. Thus if the number of teeth be 80 and $m = 10$, then the diameter $D = 8$ inches, and the circular pitch is ·314 inch, that is, 5-16th inch very nearly. Generally, the diameter and value of m being given, the number of teeth is found from the rule $N = m \times D$. Thus the value of m being 10, and the diameter 20 inches, the number of teeth is 200.

From these remarks, it is easy to perceive that this mode of sizing wheels differs from that before explained simply in this, that it expresses in small whole numbers the quantity $\frac{\pi}{P}$ instead of the quantity P, and therefore affords a ready way of calculating the diameter and number of teeth of any required wheel. This method, however, has not hitherto been introduced into millwright work; but has been confined to the sizing of small wheels of spinning and like machinery.

It has long been regarded as a rule among millwrights that the number of teeth in a wheel should be prime to the number of teeth in its pinion; in other words, that the number of teeth of the wheel should not be divisible by the number of teeth in the pinion without a remainder; and that the best possible relation of the numbers is such, that in effecting the division the remainder be 1. This *one* is termed a *hunting tooth*, and effects the purpose of preventing the same pair of teeth of the wheel and pinion from coming together until the former has made as many revolutions as it has teeth. By such an arrangement it is supposed the wear would be less uniform; and it may be observed, that if the teeth be at first incorrectly made, there is some advantage to be gained by taking prime numbers. But in the practice of the present day, when millwrights are fully alive to the method and advantages of giving to the teeth, in the construction of their wheel-patterns, the proper geometrical form, and do not trust to the wheels wearing themselves into shape, the precaution of making the numbers of the wheel and pinion prime to each other, is less required, and may, in fact, be disregarded in proportion as accuracy of construction is attained.

In respect of the relative sizes of the pairs which geer together, the main purpose to be accomplished is the modification of the contemporary velocities of the parts to such extent that their respective speeds shall be adapted to the work to be performed at the several points.

To exhibit the method of applying the principles of angular velocity to the computation of the numbers of a system of toothed geering, we shall consider, in the first place, the action of a single pair. The fundamental proposition may be stated thus:—If there be an equal pair in geer, then whether the pinion drive the wheel or be driven by it, the number of turns of the wheel multiplied by the number of its teeth, is equal to the number of turns which the pinion makes in the same time, multiplied by

the number of its teeth, so that the number of the contemporary turns of the wheel and pinion are reciprocally proportional to the numbers of their teeth.

Applying this principle to a system of geering, we deduce the following rules: To find the number of revolutions of the last pinion of the system, multiply the number of revolutions of the first wheel by the quotient which is found by dividing the continued product of the numbers of teeth of all the wheels, by the continued product of the numbers of teeth of all the pinions.

It thence also follows that the number of revolutions of the last pinion, for one revolution of the first wheel, is equal to the product of all the wheels divided by the product of all the pinions.

And conversely for one revolution of the last pinion, the first wheel will make that portion of a revolution expressed by a fraction, having for its numerator the product formed by multiplying together the numbers of the teeth of all the pinions, and for its denominator the product formed by multiplying together the numbers of teeth of all the wheels.

From these rules it immediately follows, that whether a system of geering contains one wheel and pinion, or any greater number of wheels and a like number of pinions, if we designate the product of all the wheels by W, and the product of all the pinions by P, and if p represent the number of revolutions made by the last pinion during one revolution of the first wheel, we shall have

$$W = p \times P \text{ and } p = \frac{W}{P}.$$

In reference to the *strength of the teeth of wheels*, the first subject of inquiry is the *stress* they are severally required to sustain when in action.

The fundamental principle involved in the consideration of this subject, is expressed by the condition that *the pitch being the same, the stress is inversely as the velocity;* and this is obviously true, since the teeth which act with superior force must be proportionally stronger; and the momentum of the power remaining constant, the higher the velocity becomes, the more is the weight of the power diminished, so that in any combination of wheels, the stress upon the teeth is reciprocally proportional to the velocity at a given point of the train. Thus, the strength which is sufficient to transmit a given amount of horse power, when the velocity is one foot per second, will be equal to the transmission of double that amount when the velocity is two feet a second, three times the amount when the velocity is tripled. Knowing therefore the strength of teeth necessary to transmit a given amount of horse power, the same strength of wheel will be sufficient under any other circumstances of increase, or diminution of velocity, when the horse power of the first mover in both cases, divided by the velocity in feet per second, produces the same quotient. Thus assuming as the standard the received mechanical unit of a horse power, namely, 33,000 pounds raised one foot high in a minute, or 550 pounds raised one foot in a second, then if H be the number of horses' power of any first mover, and v the velocity of the pitch circle (in feet per second) of any wheel in the system of geering moved by it, then the stress will be expressed in pounds by $\frac{550 \times H}{v}$.

For example, if the pitch line of a wheel move with a velocity of 11 feet per second, and the power of the prime mover be twenty-horse power, the stress will be $\frac{550 \times 20}{11} = 1000$ pounds.

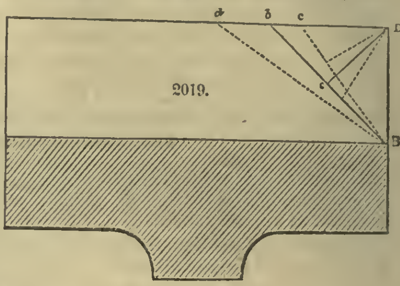
Otherwise, if P be the power of the prime mover in pounds, and V be the velocity of that power in feet per second, the stress on the teeth of a wheel through which the power is transmitted, and of which the velocity of the pitch circle is v, will be expressed in pounds as before, by $\frac{P \times V}{v}$.

It is necessary, however, to be observed, that the absolute power of the prime mover must only be considered at those points of the geering through which it is wholly transmitted; for if the power be taken off at different points, it is obvious that the stress will be successively diminished as these points are passed. For instance, the power of a steam-engine being employed to drive a cotton factory: if the first geering be so arranged that the whole power of the engine is transmitted from the fly-wheel shaft to a vertical shaft, which ascends from the bottom to the top-flat of the building, by a bevel pair, and if the geering of the several flats be successively connected with this upright shaft, it is clear that, in estimating the stress at the several points, with a view to ascertaining the requisite strength of the several pairs, the whole power of the engine ought to be taken only at the first point; that is, at the point where it is connected with the vertical shaft. In estimating the strength of the bevel pair there placed, H, in our formula, will be equivalent to the whole power given off by the engine; but at the successive points, where the power is taken off to drive the machinery of the several flats, H will represent only the amount of power requisite to do the work at these points.

A difference is besides very properly made in practice, in the strength of those wheels of a system of geering which are placed near the first mover, to compensate for irregularities in the motion; for were the strength exactly limited to the resistance to be overcome under constant action, a sudden acceleration of the speed would tend to stripe the wheels, in other words, to break the teeth. Also in operations of an irregular kind, the strength ought to be greatly more than is requisite in such geering as that of a cotton factory. Thus the geering in iron-works, and the like, is greatly beyond the strength which a calculation of the power of the prime mover would indicate, and this is required to counteract the sudden shocks which result from the checking of *rolls* and the like.

It may also be necessary to remark, that, in estimating the strain upon a system of geering, it is the actual power required to do the work which is to be taken as an element of the data—that is, the horse power at which the *resistance* is valued.

In the teeth of wheels, it is of importance that the whole be made of such strength as to sustain uninjured the greatest stress that is likely to come upon it in the course of working in the worst possible position; that is to say, in the direction in which the structure is capable of offering the least effective resistance to fracture. Now supposing the strain to act with its whole energy upon the extreme corner of a tooth, it is easy to perceive that it will there more readily produce fracture than if it acted along the whole line of the breadth; for supposing it to act along the whole line of breadth, if fracture of the tooth should take place, it must traverse the whole line A B, or some line parallel to it; but acting at D, should the force be sufficiently great to break the tooth, the fracture will take place, not along the root of the tooth A B, but in the line B b, or in some line parallel to it—these being the lines of least resistance. Rather, under the circumstances of the force being applied at D, the strain will be greatest along the line B b, which is defined from B D = D b.



2019.

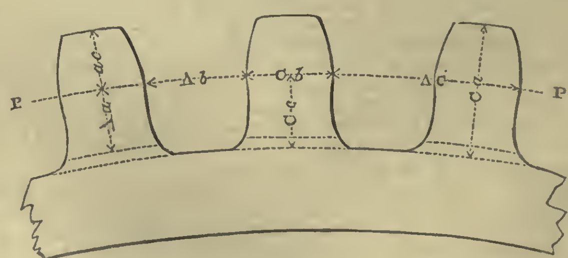
To show that this is strictly true, let it be borne in mind that the strength of beams of equal thickness is directly as their breadths, and inversely as their lengths; consequently, if the proportion of the length to the breadth be preserved, the strength will remain unaltered whatever difference is made in the actual dimensions. But this being true, it necessarily follows that the line of fracture, under the circumstances presumed, will be along the line which, as a base, bears the least proportion to the perpendicular height from that base to the point where the pressure is applied. This least proportion is when B D = D b, for the base B b is then only double the effective length of the beam, that is, double the perpendicular e D. If a line be drawn from B to d, it will manifestly be more than double the altitude of the triangle B d D, of which it is the base; and, similarly, the line B c is more than double the altitude of its triangle B c D.

This might be directly proved by application of the rules of *maxima* and *minima;* rather, it might be shown that the strain is greatest under a force acting at D, in a line determined by D B = D b, which makes B b = 2 e D.

In effect, therefore, the line B b (including all lines parallel to it) is the line of least resistance of the tooth, and consequently the line in which fracture would be produced by a force sufficiently great applied at D. Presuming, then, that wheels, in consequence of inaccuracy of workmanship, unequal wearing of brasses, vibration of shafts, and other circumstances incidental to the action of a system of geering, are liable to stress acting upon them in the least efficient position of the teeth, it would appear that the *effective* proportion of the breadth of the tooth, assuming the thickness to be uniform, does not exceed twice the length. Whatever may be the force, the principle informs us that there is a limit beyond which no strength is practically gained, and this limit will be found in general not to differ materially from double the length of the tooth.

It must not, however, be inferred from this that it is useless to make the breadth of any proportion greater than that stated; for although no additional practical strength be gained by increase of breadth, it is still highly advisable that the dimensions named should bear a much higher ratio, than is given by the consideration of the merely mathematical principle. This is accordingly followed in practice, and the advantage is, that the wearing action, by being distributed over a larger surface, does not so soon reduce the thickness, and thereby render the wheel too weak for the work it has to perform. Moreover, there is the additional advantage in giving more breadth than is indicated above, that the surfaces of contact being longer, vibration is to some extent diminished; the centres are accordingly better preserved, and the wearing of the tooth becomes greatly more uniform. An error of workmanship, and of unequal contraction of the casting, becomes likewise more apparent, and may possibly admit of correction.

2020.



As it is convenient to express all the dimensions in terms of the same unit, and the pitch being an appropriate quantity, is nearly universally adopted as the term of comparison.

These proportions differ, though slightly, in different works and in different localities; but they are the most commonly employed, and are besides the most consistent with good and accurate workmanship. For the sake of more easy reference, we collect them into a table, which the annexed Fig. 2020 will serve fully to explain. They stand thus:

ab = Pitch of teeth,	$= 1$	pitch.
ac = Depth to pitch line, P P,	$= \frac{3}{10}$	"
$Aa \times ac$ = Working depth of tooth,	$= \frac{6}{10}$	"
$Cc - Aa$ = Bottom clearance,	$= \frac{1}{10}$	"
Ca = Whole depth to root,	$= \frac{7}{10}$	"
Cb = Thickness of tooth,	$= \frac{5}{11}$	"
Ab = Width of space,	$= \frac{6}{11}$	"

These proportions, as remarked, are found to work very advantageously, and are those adopted in several workshops; but the following are preferred by some engineers of experience. Thus supposing the pitch divided into 15 equal parts: then the

Depth from point to pitch line,	$= 5\frac{1}{2}$	parts.
Depth from pitch line to root of tooth,	$= 6\frac{1}{2}$	"
Whole length of tooth,	$= 12$	"
Working depth,	$= 11$	"
Thickness of tooth, (also of arms and rim,)	$= 7$	"
Width of space,	$= 8$	"

In practice, these proportions are usually laid off in lines for the convenience of the workmen in the pattern shop, so that for any given pitch the other dimensions may at once be determined by means of the compasses, and without having recourse to calculation. In Figs. 2021 and 2022 two diagrams of that sort are given. Fig. 2021 contains the proportions last enumerated, in which the pitch is supposed to be divided into 15 equal parts; and Fig. 2022 is constructed nearly according to the proportions first given, but embraces the recognized principle that the relative amount of clearance ought to vary inversely as the pitch, wheels of small pitch requiring more clearance relatively than those in which the pitch is greater. Accordingly, in this scale, the clearance in a wheel of $\frac{3}{4}$-inch pitch is 1-10th the pitch, whereas were the scale sufficiently extended, it would show a clearance of only 1-18th for a pitch of six inches.

The construction of these scales is very simple. Thus in Fig. 2021, and to six inches pitch, let A B be divided into 15 equal parts, and draw B C perpendicular to it; and again divide B C into a determinate number of parts from B, actual measures of the pitches for which the scale is intended to be used; that is, B $a = \frac{1}{2}$ inch; B $b = 1$ inch; B $c = 2$ inches, and so on, and join a and A, b and A, c and A, and so on. To complete the scale, draw 15 parallels to B C from the points numbered in the line A B, numbering their intersections (if thought proper) with the line A C in the same order; and also the two parallels T and U, (which are full lines in the diagram,) equidistant from the parallels on each side of them.

The scale is thus ready for use, and its principle is self-evident. To get from it the several proportions for a given pitch, say of 3 inches = B d, let the compasses be extended from the intersection of the parallel marked T, with the line A B, to the point where it intersects the line A d; this will be the part of the tooth from the pitch line to the point, and equivalent to $5\frac{1}{2}$ parts of the pitch, (viz. of B d;) similarly the compasses being extended from the intersection of the parallel U, with the line A B, to its point of intersection of the line A d, will give the part of the length of the tooth from the pitch line to the root, and equivalent to $6\frac{1}{2}$ parts of the pitch. For the whole length of the tooth (if wanted in one measurement) set the compasses to the point where the parallel marked 12 meets the line A B, and extend to its point of intersection of the line A d at s, the length is 12 parts of the pitch B d; the working depth is in like manner found from the parallel marked 11; the thickness from that marked 7; and the width of space from that marked 8.

The proportions for any other given pitch comprised in the scale are found in precisely the same way, and if the scale be well constructed they may be measured off with the utmost accuracy and readiness. To save confusion it is, however, better in practice to insert in the diagram only those parallels, namely, T, U, 12, 11, 8, 7, which are required; the others are not requisite, and by inattention may lead to error. Both this scale and that marked 2 are commonly drawn on hard-wood boards; but sometimes, for the sake of greater accuracy, on plates of polished brass.

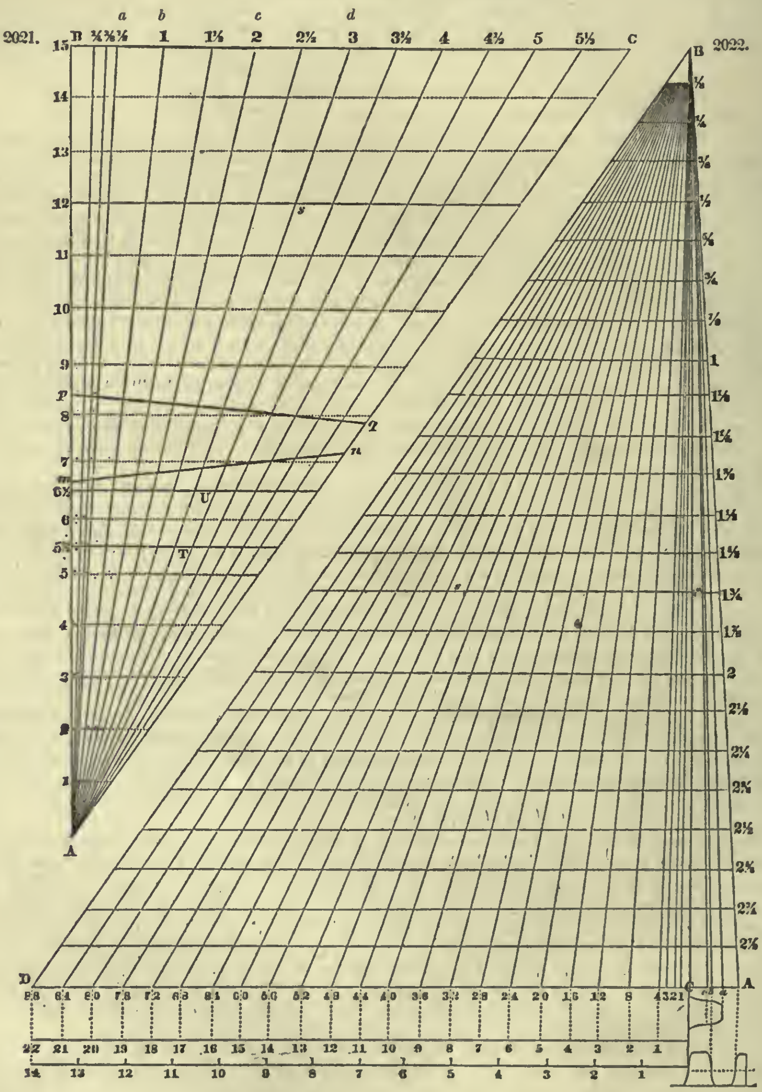
The description of the scale as here given supposes that the lateral clearance is constantly 1-15th of the pitch; but as it is commonly desired and desirable that this should vary slightly with the pitch, relatively increasing as the pitch decreases, two other lines, $m\,n$ and $p\,q$, have been introduced into the scale, to enable such modification to be adopted, should it be required. These lines are drawn at such angles as to give a clearance at 6 inches pitch of 1-18th, which is increased at $\frac{3}{4}$-inch pitch to 1-10th. From these lines the thickness and space are to be taken, instead of using the lines marked 7 and 8, setting the compasses in the points of intersection with the pitch lines, and extending perpendicularly to *the line* A B; in other words, the *shortest distance* from the point of intersection with the pitch line to the line A B, is the required measure of the space when the line $p\,q$ is taken, and of the thickness of tooth when the line $m\,n$ is taken.

Fig. 2022 is more complete than the one described, and when well constructed insures, with moderate care, a degree of accuracy and uniformity, in the construction of the various sizes of wheels for which it is employed, that can hardly be otherwise attained. The principle of its construction is in effect the same as that described, but its use is more extended; the diameter of the wheel being found from it simultaneously with the length and thickness of tooth, width of space, and clearances. The scale is adapted to wheels of all the pitches enumerated in the table, p. 795, from $\frac{1}{2}$ inch up to 3 inches. The mode of construction is this: having drawn the line A D of any convenient length, raise the perpendicular C B to it, also of any convenient length. On the line A D lay off the greatest pitch of the scale from C to A; then from C towards D lay off *seven* times the pitch *once* or *twice*, according to the sizes of wheels to which the scale is intended to be applied. In the scale given, double of seven times the

pitch is laid off, namely, 42 inches; then each of these great divisions being subdivided into 11 equal parts, one of these parts will be equal to four teeth upon the radius of the wheel, so that the whole line C D will be divided into 88 radial pitches. Next on the line C B set off the pitches which may be required in the scale, and through these points draw the 24 parallels to A D, terminating in the lines A B and D B. Then each parallel measured from the line B C to its point of termination in B D, is the radius of a wheel of 88 teeth of the particular pitch marked against it on the line A B. They also express the radii of wheels having less than 88 teeth when measured only to the corresponding point in the line joining B, and the divisional on C D, against which the number of teeth is marked. Thus the radius of a wheel of 52 teeth and 1¾-inch pitch, is $rs = 15$ 7-16th inches very nearly. (The true answer by the table, p. 795, is $30{\cdot}8724 \div 2 = 15{\cdot}4362$ inches.)

PROPORTION SCALES FOR GEERING.

2021. 2022.



The scale may also be used when the number of teeth exceeds 88; for example, to find the radius of a wheel having 100 teeth. Thus having found the radius answering to 88 teeth, upon the same parallel take off the measure answering to the difference $100 - 88 = 12$ teeth; and the two measures together will be the radius required.

To adapt the scale to odd numbers of teeth, the first division on the right of C is divided into single radial pitches, so that the radius of any wheel may be measured off without having recourse to calculation of any kind. Thus, for example, if the wheel is intended to contain 50 teeth, the compasses being

extended from 52 to the intersection of the parallel answering to the particular pitch to where it meets the line joining Q and B, will give the radius required, that is, a radius answering to $52 - 2 = 50$ teeth and any other number of teeth when not marked against the base may be found in the same way, ob serving that it is more convenient to subtract than to add in this use of the scale.

For the proportions of the teeth, set off $C\,a = 7$-*tenths* of the pitch, then will $A\,a = 3$-*tenths* of the pitch, which corresponds to the depth from the point of the tooth to the pitch line. Again, set off $C\,b = 7$-*fifteenths* of the 3-inch pitch, and 5-*elevenths* on the parallel against the 1-inch pitch; this will be the thickness of the tooth, allowing from a *fifteenth* for clearance on the largest pitch, to a *tenth* on those from $\frac{3}{4}$-inch and under; and $A\,b$ will be the width of space, including the clearance. Lines being drawn from those points to B complete the diagram, which will be found to contain all the proportions enumerated in the preceding table.

To use the scale, lay off the addendum of the tooth; that is, the length beyond the pitch line, equal to $A\,a = \frac{3}{10}$ pitch, and the same length marked off within the pitch line will give the whole working depth of the tooth, namely, 6-10ths pitch. Then with the measure $C\,a = \frac{7}{10}$ pitch in the compasses, mark off the whole length of the tooth, and this will allow 1-10th at bottom for clearance. Again, set off the thickness of tooth $= C\,b$, and the space $= A\,b$ which will contain the clearance for the particular pitch, varying from 1-15th to fully 1-10th on the small pitches. It is hardly necessary to observe that these measurements must be taken upon the parallel corresponding to the particular pitch under consideration at the time.

The amount of bottom clearance is here presumed to be uniformly 1-10th of the pitch; but if it be thought advisable to make this vary as in the case of the lateral clearance, it will then be necessary to insert a third line $c\,B$ in the scale, and so related to $a\,B$ that the space $a\,c$ shall be throughout equal to the depth of tooth from the pitch circle to the root, and giving any bottom clearance that may be desired.

In relation to the strength of wheels, M. Morin, in his *Aide Mémoire de Mécanique Pratique*, gives it as a rule that when the velocity of the pitch circle does not exceed five feet per second, the breadth of the tooth measured parallel to the axis ought to be equal to four times the thickness; but when the velocity is higher the breadth ought to be equal to five thicknesses, the teeth being constantly greased. If the teeth be constantly wet, he recommends the breadth to be made equal to six thicknesses at all velocities.

With respect to the thickness of the tooth, it is plain that it must be dependent on the pressure which the tooth is required to sustain. This relation may be conveniently expressed for all cases by the formula, $t = c\sqrt{W}$. where t is the thickness of the tooth, W the pressure upon it in pounds, and c a constant multiplier depending upon the nature of the material of which the tooth is formed.

Therefore for cast-iron $c = \cdot025$; and reasoning in the same way for brass, we find it $= \cdot035$ for hard wood, $= \cdot038$; so that for the thickness of teeth of these materials, we have,

$$\left.\begin{array}{ll}\text{For cast-iron,} & t = \cdot025\sqrt{W} \\ \text{For brass,} & t = \cdot035\sqrt{W} \\ \text{For hard wood,} & t = \cdot038\sqrt{W}\end{array}\right\}\ \text{which give } t \text{ in inches or parts of an inch, W being taken in pounds.}$$

As an example of the application of these formulæ, let it be required to find the thickness of a tooth (cast-iron) which is to sustain a pressure of 4000 pounds at the pitch circle, the breadth being double the length. Here $W = 4000$; therefore $\sqrt{W} = 63{\cdot}25$.

Hence $t = \cdot025\sqrt{W} = \cdot025 \times 63{\cdot}25 = 1{\cdot}58$ inch.

The same calculation applied with the formula for brass, would give $t = 2{\cdot}21$ inches; and for wood it gives $t = 2{\cdot}4$ inches.

The thickness of tooth given by our rules is intended to make allowance for wear at a velocity of three feet per second, and has been found to be sufficient in practice. It is, however, less by a small fraction than would be found by application of Mr. Tredgold's rule; that is, divide the stress at the pitch circle in pounds by 1500, and the square root of the result is the thickness of the tooth in inches.

To compare this rule with that given above we subjoin the following table, which will likewise be found useful in calculating the strength of wheels.

Stress in lbs. at the pitch circle.	Thickness of teeth. By Author's rule.	Thickness of teeth. By Tredgold's Rule.	Actual pitches to which the wheels would be made.	Corresponding thickness, allowing 1-10th for clearance.
lbs.	Inches.	Inches.	Inches.	Inches.
400	0·50	0·52	$1\frac{1}{8}$ to $1\frac{1}{4}$	0·536 to 0·593
800	0·71	0·75	$1\frac{1}{2}$ — $1\frac{5}{8}$	0·714 — 0·774
1200	0·87	0·90	$1\frac{7}{8}$ — 2	0·893 — 0·952
1600	1·00	1·03	2 — $2\frac{1}{8}$	0·952 — 1·012
2000	1·12	1·15	$2\frac{1}{4}$ — $2\frac{3}{8}$	1·031 — 1·132
2400	1·22	1·26	$2\frac{1}{2}$ — $2\frac{5}{8}$	1·190 — 1·250
2800	1·32	1·36	$2\frac{5}{8}$ — $2\frac{3}{4}$	1·250 — 1·309
3200	1·41	1·43	$2\frac{7}{8}$ — 3	1·369 — 1·429
3600	1·50	1·56	$3\frac{1}{8}$ — $3\frac{1}{4}$	1·488 — 1·548
4000	1·58	1·63	$3\frac{1}{4}$ — $3\frac{3}{8}$	1·548 — 1·607
4400	1·66	1·70	$3\frac{3}{8}$ — $3\frac{1}{2}$	1·607 — 1·667
4800	1·73	1·78	$3\frac{1}{2}$ — $3\frac{5}{8}$	1·667 — 1·726
5200	1·80	1·86	$3\frac{5}{8}$ — $3\frac{3}{4}$	1·726 — 1·786
5600	1·87	1·93	$3\frac{3}{4}$ — 4	1·786 — 1·904
6000	1·94	2·00	4 — $4\frac{1}{4}$	1·904 — 2·024

The last column of this table is calculated from the expression *pitch* $t. = (2 + \frac{1}{10}) = 2.1\,t.$ the clearance being a tenth. The thickness, allowing 1-15th for clearance, may in like manner be calculated from the expression *pitch* $= t.\ (2 + \frac{1}{15}) = 2{\cdot}067\ t.$

The formula reduced to expressions giving the pitch p in the same manner as the thicknesses are given above, will stand thus:—

	Clearance a tenth.	Clearance a fifteenth.
For cast-iron teeth	$p = {\cdot}0525 \sqrt{W}$ and	$p = {\cdot}0517 \sqrt{W}$.
For brass teeth	$p = {\cdot}0735 \sqrt{W}$ and	$p = {\cdot}0723 \sqrt{W}$.
For wooden teeth	$p = {\cdot}0798 \sqrt{W}$ and	$p = {\cdot}0785 \sqrt{W}$.

By means of these rules the pitch may be directly calculated. Thus, for a pressure of 15,000 pounds we have,

$$\sqrt{W} = \sqrt{15{,}000} = 122{\cdot}5.$$

Consequently, the pitch of a cast-iron wheel capable of sustaining that pressure at the pitch circle, allowing 1-15th for clearance, will be

$${\cdot}0517 \sqrt{W} = {\cdot}0517 \times 122{\cdot}5 = 6{\cdot}333 \text{ inches.}$$

The wheel from which this example is taken has been several years in action, and has an actual pitch of six inches, and the mean pressure at the pitch circle is 14·786 pounds.

It may be here observed that it is common, in calculations relative to the strength of the teeth of wheels, to make additional allowance for wear of the pinion; for if the pinion make double the number of revolutions made by the wheel with which it is engaged, its teeth will manifestly be subject to double the amount of wear by friction; consequently, to proportion the teeth of the pair so that they shall wear equally long, it is necessary to give an allowance of thickness on those of the pinion equivalent to the increase of abrasion to which they are subject. If we assume one-third the thickness as the proper allowance, this will give for the thickness of the pinion the expression $\frac{(2+n)\,t}{3}$, in which n is the number of revolutions which the pinion makes for one revolution of the wheel, and t the thickness of the teeth of the wheel. Thus, for example, if the pinion make $2\frac{1}{2}$ times as many revolutions as the wheel, of which the thickness of the teeth is 1·12 inch, then the thickness of those of the pinion will be

$$\frac{t\,(2+n)}{3} = \frac{1{\cdot}12\,(2 + 2{\cdot}5)}{3} = 1{\cdot}68 \text{ inch.}$$

This amount of difference, is not, however, commendable in practice, at least in spur-geer, and it is therefore rarely adopted, as wheels would in that case require to be constantly made in pairs, which would lead to an endless accumulation of wheel patterns. Instead of making the allowance spoken of, the common practice is to adopt a larger pitch—rather, indeed, to use wheels somewhat beyond the strength which is requisite for the work.

It has already been shown that by a horse power is meant a pressure of 33,000 pounds moved with a velocity of *one* foot in a minute. But this is the mean of the force exerted, and as most prime movers are more or less variable in their motion, any wheel required to transmit that motion should be strong enough to bear the maximum force with safety. For ordinary and general purposes we may assume, as a very safe approximation, that it exceeds the mean of the whole force exerted by the fraction 3-11ths. Making that allowance, we shall have, as the practical strain of a horse power, 550 lbs. $\times\ 1\frac{3}{11} = 700$ lbs. raised one foot per second. By substitution of this value of the horse power, in the rule formerly given, it will become $\frac{700}{v} \times H =$ the stress on the teeth of the wheel in pounds.

As an example, let a steam-engine of 12-horse power be applied to drive the machinery of a factory, and let it be required to find the strength of the teeth of a first wheel on the main shaft, which will have a velocity of four feet a second, at the pitch circle.

Here $H = 12$ and $v = 4$; therefore $\frac{700}{v} \times H = \frac{700}{4} \times 12 = 2100$ lbs., the pressure at the pitch circle $=$ W in the rule for the thickness of teeth.

Now the square root of 2100 is 45·826, and supposing the wheel to be of cast-iron, then we have

$$t = {\cdot}025 \sqrt{W} = {\cdot}025 \times 45{\cdot}826 = 1{\cdot}1456 \text{ inch,}$$

the thickness of the teeth of the wheel; consequently, if 1-10th be allowed for clearance, the pitch wil be $1{\cdot}1456 \times 2{\cdot}1 = 2{\cdot}52$ inches. The actual pitch would therefore be made from $2\frac{1}{2}$ to $2\frac{5}{8}$ inches.

If the wheel have wooden teeth, then the rule $t = 038 \sqrt{W}$ must be used, which gives 1·74 inch as the thickness of tooth, and 3·66 inches as the pitch; the pitch to be adopted would therefore be $3\frac{3}{4}$ inches.

When cast-iron and wooden teeth work together, their action upon each other tends, in consequence of the elasticity of the wood, to maintain a more uniform distribution of the strain, and being at first commonly more accurately dressed, to prevent abrasion of the wood by the iron, they work with much less friction, are less liable to shocks, and nearly exempt from accident by hard particles coming between the teeth.

The best practice, when a mortise and iron wheel are to work together, is to make both of the same pitch, and in the first instance, of the same thickness of tooth—the pitch being of course calculated for the wooden wheel by the rule $p = {\cdot}0785 \sqrt{W}$, which allows 1-15th for clearance, (and with good workmanship this is amply sufficient in cases of the kind proposed;) afterwards to dress down the teeth of the iron wheel, by the *chipping* tool, or the wheel-cutting machine, and file, to the exact form and thickness, as given by the formula $t = {\cdot}025 \sqrt{W}$; that is, to a thickness in relation to the thickness of the wooden teeth, which shall have the ratio of 25 to 38. Both of the wheels will then be of the same

strength, and from their superior finish, will work with much less friction, and, consequently, less wear than if both wheels were of iron.

If m be the number of revolutions to be made by the wheel in a minute, and n the number of teeth to be cut on it, and W the pressure upon each tooth in lbs., we shall have the following values of the pitch p in inches and parts of an inch, agreeable to the method adopted in the preceding rules, namely,

$$\text{For cast-iron } p = 12\sqrt[3]{\frac{H}{mn}} \text{ or } \sqrt[3]{\left\{\frac{1728\ H}{m\ n}\right\}} = p$$

$$\text{For Brass } . \ p = 13\sqrt[3]{\frac{H}{mn}} \text{ or } \sqrt[3]{\left\{\frac{2197\ H}{m\ n}\right\}} = p$$

$$\text{For hard wood } p = 14\sqrt[3]{\frac{H}{mn}} \text{ or } \sqrt[3]{\left\{\frac{2744\ H}{m\ n}\right\}} = p$$

Conversely, the power which the teeth of a wheel of given pitch are capable of transmitting may be readily calculated from the following rules, which are immediately deduced from the above:

$$\text{For cast-iron . . } H = \frac{m\,n\,p^3}{12^3} \text{ or } \frac{m\,n\,p^3}{1728}$$

$$\text{For brass . . . } H = \frac{m\,n\,p^3}{13^3} \text{ or } \frac{m\,n\,p^2}{2197}$$

$$\text{For hard wood . } H = \frac{m\,n\,p^3}{14^3} \text{ or } \frac{m\,n\,p^3}{2744}$$

Thus supposing the pitch $p = 3$ inches, the number of teeth $n = 60$, and the number of revolutions n which the wheel is designed to make per minute $= 50$; then the wheel being cast-iron, the power H which it is capable of transmitting will be

$$H = \frac{60 \times 50 \times 3^3}{1728} = 47 \text{ horses' power nearly.}$$

This wheel is employed to transmit 45 horses' power at the given velocity, and has been at work for several years.

Every writer on the teeth of wheels has thought it necessary to adduce rules for finding the proper breadth of the teeth. As respects strength, such a calculation has been shown to be in a manner unnecessary beyond merely doubling the length, which is immediately deducible from the pitch; and as respects durability there seems to be no theoretical limit to the breadth, for the more the pressure and rubbing action is diffused, the less rapidly will the teeth be worn. The breadth to be assigned in practice must, therefore, be always a quantity to be determined by circumstances, and modified by the particular opinions of those concerned; if the motion be particularly uniform and free of vibration, the breadth may be extended even to four times the pitch with advantage; but if the contrary circumstances obtain, this great breadth will in like manner have a contrary effect, the teeth becoming frequently locked together, will more speedily wear out of shape if they be made too strong to twist and break one another out at the ends. When the shafting is light, this is a frequent occurrence, although the reason does not seem to be always understood; and accordingly, the remark is not uncommon, that the wheel ought on account of its great breadth to have been more than sufficient for the work. However contradictory it may appear, strength in this sense is not an unfrequent cause of weakness and failure.

Assuming that the teeth of wheels follow the same law of strength by increase of breadth as in thickness, and referring back to the general formula for the strength of a beam of given dimensions, we arrive at the conclusion that the breadth b and the length l are in the relation of $b = \frac{6}{5}\,l$; and supposing with some engineers of experience that a breadth of 6 inches is sufficient for a power equivalent to 9 horses, when the pitch line moves with a velocity of 3 feet per second, then we have the following rule: Double the number of horses' power of the prime mover, and divide the result by the velocity of the pitch circle in feet per second: the result is the breadth of the teeth in inches.

Thus the power transmitted by a wheel moving at $5\frac{1}{2}$ feet velocity per second, transmits 16 horses' power; the breadth of the wheel will therefore be

$$\frac{2 \times 16}{5\frac{1}{2}} = \frac{3{\cdot}2}{5{\cdot}5} = 5{\cdot}82 \text{ inches nearly.}$$

Again, on the same principle, having the breadth and velocity of teeth given, multiply the velocity of the pitch circle in feet per second by the breadth of the teeth in inches, and half the product will be the number of horses' power which the wheel is capable of transmitting.

Thus, let the breadth be 12 inches, and the velocity 21 feet per second; then $12 \times 21 = 252$, half of which is 126, the number of horses' power required.

It is easy to see, however, that unless the breadth be a function of the pitch, any calculation of this kind cannot be satisfactory; and from the remarks already made, there cannot exist such difficulty in fixing upon the proper breadth the wheel ought to have for the particular purpose intended.

The following table may be useful in determining the relation of the dimensions of the teeth of wheels of the given pitches, and the power which they are capable of transmitting safely at the various speeds named. The table was originally constructed from the formula $\frac{2\,p^2 \times v}{5} = H$, and has since been extensively used.

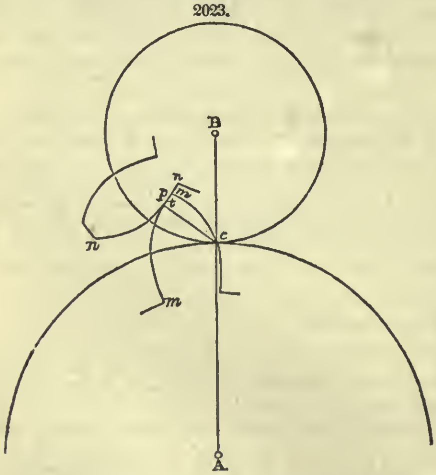
Pitch.	Thickness of teeth.	Length of teeth.	Least breadth of teeth.	Velocity of the wheel at the pitch circle.				
				3 feet per second.	4 feet per second.	5 feet per second.	7 feet per second.	11 feet per second.
Inches.	Inches.	Inches.	Inches.	H. P.	H. P.	H. P.	H. P.	H. P.
6	2·9	4·2	8·4	$43\frac{1}{5}$	$57\frac{3}{5}$	72	$100\frac{1}{5}$	$158\frac{2}{5}$
$5\frac{1}{2}$	2·6	3·85	7·7	$36\frac{3}{10}$	$48\frac{2}{5}$	$60\frac{1}{2}$	$84\frac{7}{10}$	$133\frac{1}{10}$
4	1·9	2·8	5·6	19	$25\frac{1}{2}$	32	45	$70\frac{1}{2}$
$3\frac{1}{2}$	1·6	2·45	4·9	$14\frac{3}{4}$	$19\frac{1}{2}$	$24\frac{1}{2}$	$34\frac{1}{4}$	54
3	1·4	2·1	4·2	11	$14\frac{1}{2}$	18	25	$39\frac{1}{2}$
$2\frac{1}{2}$	1·2	1·75	3·5	$7\frac{1}{2}$	10	$12\frac{1}{2}$	$17\frac{1}{2}$	$27\frac{1}{2}$
2	0·95	1·4	2·8	$4\frac{3}{4}$	$6\frac{1}{4}$	8	11	$17\frac{1}{4}$
$1\frac{3}{4}$	0·83	1·225	2·45	$3\frac{1}{2}$	5	$6\frac{1}{4}$	$8\frac{1}{2}$	$13\frac{1}{2}$
$1\frac{1}{2}$	0·71	1·05	2·1	$2\frac{3}{4}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$6\frac{1}{4}$	10
$1\frac{1}{4}$	0·59	0·875	1·75	2	$2\frac{1}{2}$	$3\frac{1}{8}$	$4\frac{1}{5}$	$6\frac{4}{5}$
$1\frac{1}{8}$	0·53	0·7875	1·575	$1\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$5\frac{1}{2}$
1	0·48	0·7	1·4	$1\frac{1}{5}$	$1\frac{3}{5}$	2	$2\frac{4}{5}$	$4\frac{2}{5}$
$\frac{7}{8}$	0·41	0·6125	1·225	1	$1\frac{2}{5}$	$1\frac{3}{4}$	$2\frac{1}{2}$	$3\frac{4}{5}$
$\frac{3}{4}$	0·36	0·525	1·05	$\frac{7}{10}$	$\frac{9}{10}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$2\frac{1}{2}$
$\frac{5}{8}$	0·33	0·4375	0·875	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{7}{10}$
$\frac{1}{2}$	0·24	0·35	0·7	$\frac{3}{10}$	$\frac{2}{5}$	$\frac{1}{2}$	$\frac{7}{10}$	$1\frac{1}{10}$
$\frac{3}{8}$	0·18	0·2625	0·525	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{3}{10}$	$\frac{2}{5}$	$\frac{3}{5}$
$\frac{1}{4}$	0·12	0·175	0·35	$\frac{3}{40}$	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{7}{40}$	$\frac{11}{40}$

To find the power which a wheel is capable of transmitting for other velocities than those in the table:—For 6 feet per second, double the result given for 3 feet; for 8 feet double the result at 4 feet, and so on; and for lower velocities than those given, divide the tabular number by the ratio which they bear to those enumerated. Thus, for $2\frac{1}{2}$ feet velocity, take half the result at 5 feet, and so of other velocities.

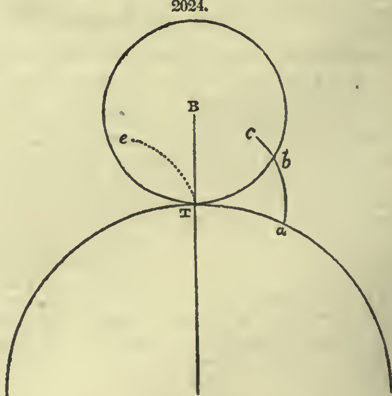
When a wheel and pinion, which differ very much in size, work together, the teeth of the latter, on account of their unequal thickness, are capable of sustaining much less pressure than the teeth of the wheel: they are in effect, if not in fact, much reduced in thickness; and, in applying rules to the calculation of the strength of wheels, the difference of size of the pair ought not to be overlooked, unless, as is indeed very common in practice, the deficiency of strength be made up to the pinion by a flange cast on one or both sides of the rim, of the same depth as the teeth, and binding these together like the staves of a trundle. In this case the pinion is commonly the stronger wheel of the pair.

In the construction of wheels, the problem which presents itself relative to the shape of the teeth is this, that the surfaces of mutual contact shall be so formed that the wheels shall be made to turn by the intervention of the teeth, precisely as they would by the friction of their circumferences.

2023.



2024.



Thus, if we take Fig. 2023 to represent two teeth of a pair of wheels of which that marked A is the driver; then it is plain that the faces of the teeth may be of such curvature in relation to each other, that as the circle A revolves and carries with it the circle B by their mutual contact at C, the teeth may continually touch one another throughout their lines of curvature, continually altering their relative positions and their point of contact t, as the primitive circles change their point of contact; and this being true, it evidently follows that the two circles would be made to revolve by the contact of teeth, whose surfaces are thus formed, precisely as they would by the friction of their circumferences

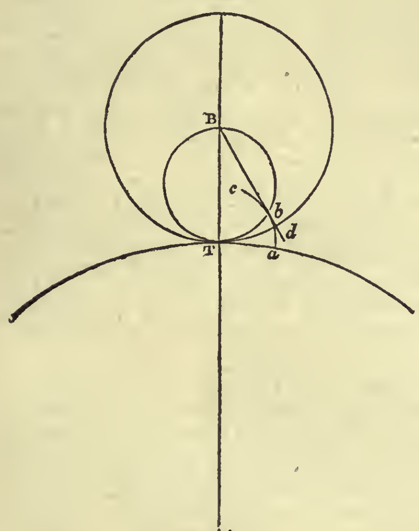
at the point c. For observing the action of the circles upon each other, in the former case we find a series of points of contact passing through c, and bringing about a corresponding rotation of points of contact of the teeth at t; and in the latter case, the action being transferred to the teeth, the same transposition of the points of contact at t is followed by the same transposition of points, as formely, through c.

To form teeth whose surfaces of contact shall possess the property here assigned to the curves of the teeth $m\,m$ and $n\,n$, is the problem to be solved; and the solution is dependent on the following

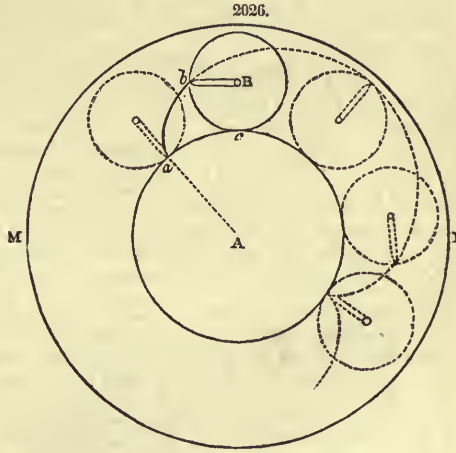
Fundamental principle.—In order that two circles A and B may be made to revolve by the contact of the surfaces of the curves $m\,m$ and $n\,n$ of their teeth precisely as they would by the friction of their circumferences, it is necessary and sufficient that a line drawn from the point of contact t of the teeth to the point of contact c of the circumferences, (pitch circles,) should in every position of the point t be perpendicular to the surfaces of contact at that point; that is, in the language of mathematicians, that the straight line be a *normal* to both the curves $m\,m$ and $n\,n$.

In proceeding to establish this principle, we must in the first place recur to a proposition, which in effect is that employed by the mechanic in the use of his *templets* for drawing in the curves of the teeth. Thus if we have two circles, as in Fig. 2024, described about A and B as fixed axes, and these circles be free to revolve by their mutual contact at T; then supposing A B the line of centres divided as usual in T, in the inverse ratio of the angular velocities of the circles; if the circle B be provided with a fine tracing point fixed into its circumference, and it be made to *roll* upon A, the point will describe the curve $a\,b$. Again, if the curve $a\,b$ continued to c be cut out of thin plate and caused to turn round the centre A, and the pin at b be carried by an arm round the centre B, the motion communicated by the pin to the curve will fulfil the required conditions. For at the beginning of the motion let T e be the position of the curve, then the pin will coincide with T; and if the curve move into any other position $a\,b\,c$, driving the pin to b, the arc T a will be equal to T b, and the path described by the pin in its motion will be that indicated by $a\,b$. But the arcs T a and T b are also those described by the two pitch circles respectively in moving from T to the second position, and since these equal arcs are described in the same unit of time, the angular velocity is not charged, but remains constant as if the motion had been produced by the rolling contact of the two pitch circles.

2025.



2026.



A further illustration of the same principle is afforded by Fig. 2025, in which A and B are centres of motion, as before, and T the point of contact of the pitch circles of the wheels. In this case, let the curve $a\,b\,c$ be described by a point b fixed in the circumference of a circle T b B, having for its diameter the radius B T of the pitch circle of the wheel B. From the centre B, let a radial line B b be drawn, touching b and meeting the pitch circle in d. Further, let motion be communicated by contact from the edge $a\,b\,c$ of the curve which revolves about the centre A to the radial line B b d, which revolves about B, and let the beginning of the motion be reckoned from the position in which a coincides with T, and therefore d with a; then in moving to any other position of contact, the arcs simultaneously described by the two pitch circles will be T a and T d. Now T B b is an angle at B, the circumference of the rolling circle, and T B d an angle at the same point, which is the centre of the pitch circle; therefore T b measures an angle double of T d. Also the radius T b is half that of T d, consequently the arc T b = T d = T a; that is, the arcs of the pitch circles measured from the beginning of motion are equal, and therefore the angular velocity ratio, as before, is constant and the same as would be obtained by the rolling contact of the pitch circles.

To exhibit this principle in another point of view, let there be two circles having their axes in A and B, and their point of contact c as shown in Fig. 2026; then supposing that the circle B is made to *roll*

upon the circumference of A, a point in the circumference of the former will describe a curve *a b*; that they are applied by their axes to a third plane M M, into which their axes are fixed, and which has also an axis of motion coinciding with A; then it is evident if the plane M M be made to move while the circle on A is kept at rest, the circle upon B will be made to revolve upon the circumference of this last, and a point *b* fixed into its circumference will trace out a curve *a b* upon the plane M M, precisely the same as would have been described by that point, if the latter plane had remained at rest, and the centre of the circle B had been set free from its axis, and been made to roll by its circumference on the circumference of A. This is obvious, and it is also obvious that, both circles being fixed by their axes to the plane M M, and the circle on A being made to revolve with an equal, but opposite angular velocity to M M, and which communicates its angular velocity to the circles A and B, these revolving meantime in respect to one another, and by the mutual contact of their circumferences precisely as they would if the plane M M were at rest, then the circle A being carried round by its own proper motion in one direction, and by the motion common to it, and the plane M M with the same angular velocity in the opposite direction, will in point of fact *rest in space;* and at the same time the circle B having no motion proper to itself, will revolve with the angular velocity of the plane M M, and all the points of that circle will have angular velocities compounded of their proper velocities, and the velocities they receive in common with the plane M M; but these velocities being equal and opposite at the point *c*, will there neutralize one another. Now this point *c* is the point of contact of the two circles; so that while B revolves about A, the point *c* at which it is in contact with the latter is at rest; yet this quiescent point of the circle B is continually varying its position on the circumferences of the two circles, so that the circle B is thus made to *roll* on the circle A, which, in consequence of its own proper motion in one direction being neutralized by the equal and opposite motion it receives from the plane M M, is in reality at rest.

It therefore appears that by communicating a certain common angular velocity to both the circles A and B about the centre A, the former is made to *roll* upon the latter at rest, and moreover that this common angular velocity does not alter the form of the curve *a b*, which a point *b* in the circumference of B describes upon the plane M, that is, in effect upon the plane of the circle A; in other words, that the curve traced under these circumstances is the same whether the circles revolve about fixed centres by their mutual contact, or whether the centre of one circle be released and it be made to *roll* upon the circumference of the other at rest. And this shown to be true, the principle announced becomes evident; for if B roll on the circumference of A, it is evident that a point *b* will at any instant be describing a circle about their point of contact *c*, and this being true, it likewise follows that the point *b* is at every instant of the revolution describing during that instant an exceedingly small circular arc about *c*, and therefore is *b c* always perpendicular to the curve *a b* at the point *b*; in other words, it is always a *normal* to it.

Now returning to Fig. 2023, let P be a point exceedingly near to *t* in the curve *n n*, which is fixed upon the circle B; it is evident from what has been shown, that as that point passes through the point of contact *t* of the two curves, it will be made to describe on the plane of the circle A an exceedingly small portion of the curve *m m*. But the curve which under these circumstances it describes, has been shown to be always perpendicular to the line *t c*, now the curve *m m* being perpendicular to that line at *t*, the point of contact with *n n*, that curve must likewise be perpendicular to it at the same instant, and consequently we have *t c*; a *normal* to both curves at the point *t*. This is the characteristic property of the two curves *m m* and *n n* by which they satisfy the condition of a continual contact with each other at the same time that the circles revolve by the contact of their circumferences at *c*; and conversely, supposing the motion to be induced by the mutual contact of the curves, they will communicate the same motion to the circles, as these would receive by the mutual contact of their circumferences.

The principle here announced, exhibits a special application of one particular property of that curve known to mathematicians as the *epicycloid.* The mode of generating it is that described, and that upon which a mathematical definition of it is founded. Thus generally when two circles are in contact at their circumferences, and the one is made to roll upon the other, any point beyond the centre in the moving circle describes during its revolution the particular curve named. This curve, as already stated, may be traced upon an immovable plane, against which a point in the moving circle is made to bear. For the sake of distinctness this is termed the *generating* circle, and the circle upon which it rolls is called the *fundamental* circle, and the portion of it on which the epicycloid rests is called the *base.*

The definition of the epicycloid is rendered obvious by reference to Fig. 2026, in which B is the generating circle, and A the fundamental circle of the epicycloidal curve *a b*. If the generating circle, instead of rolling on the outside, roll *within* the base circle, the curve is usually called an *interior epicycloid;* that generated when the circle rolls on the convex circumference, being termed for distinction an *exterior epicycloid.*

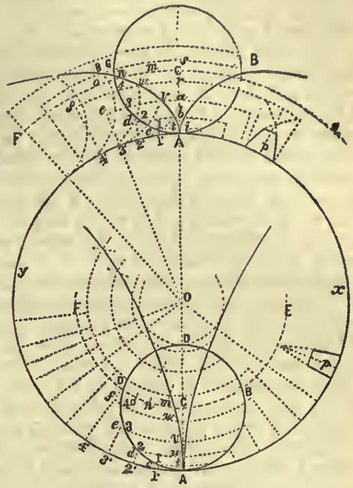
An essential condition of the epicycloid is that the generating circle, in revolving from its first position to different other situations, as shown in Fig. 2026, applies successively all the parts of its circumference to those of the base; it is therefore evident that the base of the complete epicycloid is equal to the circumference of the generating circle, and each portion of its base as *c a* is equal to the corresponding part *c b* of the generating circle by the rolling of which it is traced. Hence we have a method of drawing the epicycloid by describing a series of circles which have all the same diameters as the generating circle B, and which all touch the base A; then making the lengths of the arcs *c b* taken from the points of contact with the base equal to the arcs *c a* of the base, we can readily determine the points of the curve, and consequently the curve itself.

The epicycloid may be described by the compasses in the following manner. Let us in the first place take the exterior curve.

Having divided the circumference A B D, Fig. 2027, into a series of equal parts 1, 2, 3, ... beginning from the point A; set off in the same manner, upon the circle A *x* A *y*, the divisions 1′, 2′, 3′, ..

equal to the divisions of the circumference A B D. Then, as the circle A B D rolls upon the circle A x A y, the points 1, 2, 3, will coincide successively with the points 1′, 2′, 3′; and, drawing radii from the point O through the points 1′, 2′, 3′, and also describing arcs of circles from the centre O, through the points 1, 2, 3, ... they will intersect each other successively at the points *c d e*, ... Take now the distance 1 to *c*, and set it off on the same arc from the point of intersection of the radius A C to *t*; in like manner, set off the distance 2 to *d*, from *b* to *u*, and the distance 3 to *e* from *a* to *v*, and so on. Then the points A *t u v*, ... will be so many points in the epicycloid; and their frequency may be increased at pleasure by shortening the divisions of the circular arcs. Thus the form of the curve may be determined to any amount of accuracy, and completed by tracing a line through the points found.

2027.



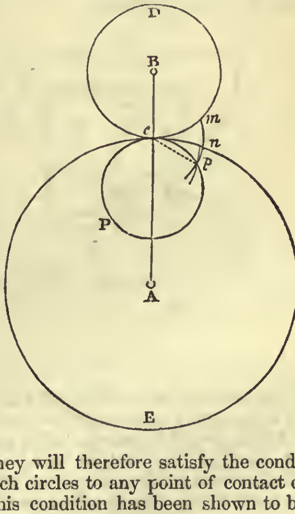
As the distances 1 to *c*, ... which are near the commencement of the curve, must be very short, it may, in some instances, be more convenient to set off the whole distance *t* to 1 from *c* to *t*′, and in the same way the distance *b* to 2 from *d* to *u*², and so on. In this manner the form of the curve is the more likely to be accurately defined.

A second method of finding the points in the curve is, in the first place, to find the positions *m n*, of the centre of the rolling circle corresponding to the points of contact 1′, 2′, 3′, &c., which may be readily done by producing the radii from the centre O, to cut the circle E F. From these centres describe arcs of a circle with the radius of C A, cutting the corresponding arcs described from the centre O, and passing through the points *t u v*, as before.

Two distinct portions of the curves are represented in combination so as to form the faces of a tooth of a wheel of which the primitive circumference is A *x* A *y*.

When the moving circle A B D is made to roll on the interior of the circumference A *x* A *y*, as shown in the under part of Fig. 2027, the curve described by the point A is called an *interior epicycloid.* It may be constructed in the same way as in the preceding case. The first operation is to divide the two circles into equal parts, at the points 1, 2, 3, and 1′, 2′, 3′, &c. Draw radii from the points 1′, 2′, 3′, &c., to the centre O, and also arcs of circles through the points 1, 2, 3, &c., from the same centre O, meeting the corresponding radii at the points *c d e*. Then by transferring the distances *c* to 2, *d* to 3, to the axis A D, as in the other case, we find a series of points *t u v*, which may be increased in number to any extent, and are points in the curve, through which, if a line be traced, the epicycloid will be formed.

2028.



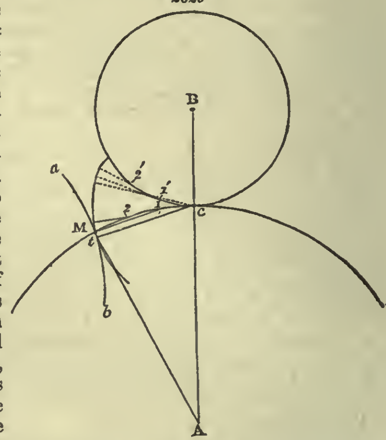
To determine the relation of the epicycloid and hypocycloid in connection with the form of the teeth of wheels, let *m p* and *p n*, Fig. 2028, be respectively portions of these curves, having the same generating circle *c* P *p* and having for their bases the pitch circles *c* D *c* and *c* E *c* of two wheels. If the faces of the teeth upon the circumferences of these wheels coincide with these curves, it may be shown that they will work truly together; for let them be in contact at *p*, and let their common generating circle be in contact with both pitch circles at *c*, then will its circumference manifestly pass through the point of contact of the two teeth: and if it were made to roll through an exceedingly small angle upon the point *c*, rolling there upon the circumferences of both circles, its generating point would traverse exceedingly small portions of both curves. But since a given point in the circumference of the generating circle is thus at the same instant in the perimeters of both the curves, that point must of necessity be the point *p* of the curves; and since moreover the generating circle rolls upon the point of contact *c*, its generating point traverses a small portion of the perimeter of each of the curves at *p*, it follows that the line *c p* is a normal to both curves at that point; for whilst the generating circle *c* P *p* is rolling through an exceedingly small angle upon *c* the point *p*, it is describing a circle whose radius is *c p*. If the teeth of a pair of wheels have their edges formed to these curves, they will therefore satisfy the condition that the line *c p*, drawn from the point of contact of the two pitch circles to any point of contact of the teeth, is a normal to the surfaces of both at that point, and this condition has been shown to be necessary and sufficient to the correct working of the teeth.

From this then it appears that if an epicycloid be described on the plane of one of the wheels with any generating circle, and with the pitch circle of that wheel for its base; and if a *hypocycloid* be described on the plane of the other wheel with the pitch circle of *that* wheel as *its* base, and if the acting surfaces of the teeth on the two wheels be cut so as to coincide with these curves, they will be driven by the intervention of these teeth in the same manner as they would by simple contact of their pitch circles.

It might be shown in exactly the same manner that the curves *m p* and *n p* may be generated by the rolling of any other curve than a circle upon the pitch circles of the wheels; they would still possess

this property, that a line drawn from any point of their contact to the point of contact of the pitch circles is a normal to both, which, as already shown, is the one necessary and sufficient condition. Further, it can be shown that a tooth of any form whatever being cut upon a wheel, it is possible to find a curve which, rolling upon the pitch circle of that wheel, shall, by a certain generating point, traverse the edge of the given tooth; and the curve thus found being made to roll on the circumference of a second wheel, will trace out the form of tooth which will work truly with the first.

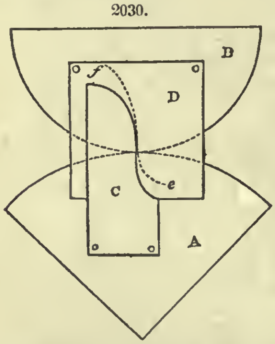
2029



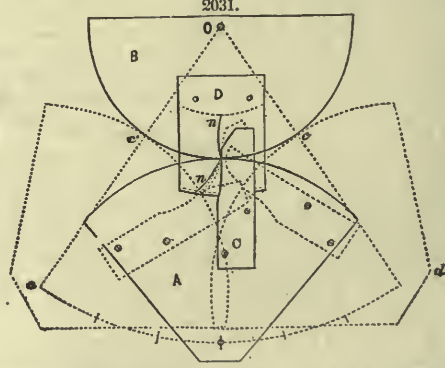
Let $a\,M\,b$, Fig. 2029, be any curve whatever intended to form the condition of the acting surfaces of teeth of the wheel, and let $c\,M$ be the pitch of the wheel; take $c\,m = c\,M$, it is required to find the curve which passes through the point m, and which being continually in contact with the curve $a\,M\,b$ will be impelled by the latter according to the required condition. Now, as the common normal must always pass through the point c, if we draw the perpendicular $c\,t$ to the curve $a\,M\,b$, which may be done by describing an arc of a circle from the point c as a centre, with a radius such that that arc will cut the curve $a\,M\,b$ in two points infinitely near and joining the point c to the middle of the distance of these two points, the point t will be the point of contact of the two curves. Supposing now that we divide the pitch $c\,M$ and $c\,m$ into the same number of equal parts at the points 1, 2 and 1′ 2′, when these points arrive successively in contact in the course of the revolution of the two circles, they will coincide with the point c; and the normal to the curve $a\,M\,b$, passing through the point 1, will also be the normal to the curve sought, and will pass through its point of contact with $a\,M\,b$. If, then, from the point 1′ as a centre, with a radius equal to a normal to the curve $a\,M\,b$, we describe an arc of a circle, it will be a tangent to the curve sought. And doing the same with the other points of division, we find a number of points through which, if a curve be traced tangential to the small arcs described, it will fulfil the conditions of the problem, with more or less accuracy, according as the points taken have been more or less numerous.

From this it therefore appears that, having the curve given of the teeth of one wheel, the curve to which the teeth of the second wheel ought to be formed may be readily found; which is the problem in its most general form, and may be stated summarily thus: Given the form of the teeth of one wheel, to find out the form of those of another that may work with it correctly. *Solution:* Describe the pitch circles of the required wheels, and find the curve which, revolving upon the one, will describe the given tooth; make the same curve revolve within the other, and with the same describing point it will generate the tooth required.

2030.



2031.



It is however to be observed, that these curves, to be applicable in practice, imply the condition that the curvature of the concavity of one tooth should be greater than the convexity of the other, or else that both should be convex. The practical solution may be conducted in the following simple manner: Let A and B, Fig. 2030, be two boards, whose edges are formed into arcs of the given pitch circles. Attach to one of them the shape of the proposed tooth C, and to the other a piece of strong paper D, the tooth being slightly raised to allow the paper to pass under it. Keep the circular edges of the board in contact, and make them roll together. Draw upon D a number of successive positions of the outline of the edge of C, which, touching one another in a corresponding number of points, a curve $f\,e$, passing through these points, will be the corresponding tooth required for B. For it is obvious, from the method it is obtained, that if the tooth be cut out, and be made to work upon C, it will touch that tooth in every position; and therefore the contact of these curves will exactly fulfil the required condition, by replacing the rolling action of the two pitch circles.

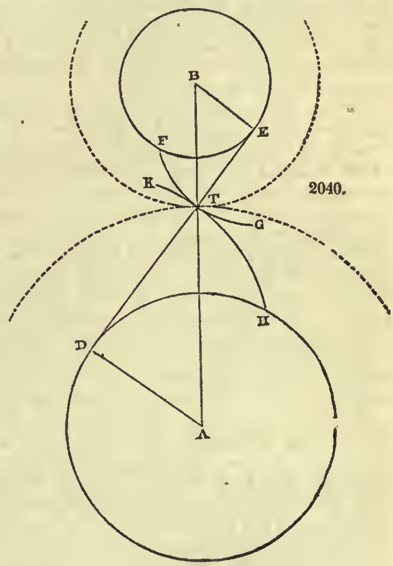
To illustrate the preceding process more particularly; by means of Fig. 2031, let o be the centre of the piece B, supposed to be fixed; and suppose the piece A rolling upon it over the arc $c\,c'$ of sufficient extent to include the extreme positions of the acting surfaces. Then c and c', being the extreme points

of contact of the pieces, draw the radii $o\,c$, $o\,c'$, and from the centre o, with a convenient radius, draw an arc $d\,e$, meeting $o\,c$ and $o\,c'$, produced at d and e; divide this arc into a number of equal parts, corresponding to the number of positions of the tooth C intended to be taken; the radii drawn to the points of division will give corresponding points of contact at the circumference of the piece B, from which the relative positions of the tooth C may be severally described. In Fig. 2039, the extreme positions of the piece A and the tooth C are indicated by dot lines, though, with the exception of two other positions of the tooth, the rest is omitted to prevent confusion. A curve $n\,n$, being traced so as to touch, in succession, the different positions of the tooth C, will indicate the form of tooth required for the piece B, so as to geer with the piece A.

It is, however, true, that many forms of C may be tried which will prove impracticable; for some of the successive portions of its edge may come up and interfere with parts of $a\,b$, previously drawn; thereby showing, that although it may be geometrically possible to assign a form of $a\,b$, which shall work with any given form of C, it by no means follows that this is practically true; and, indeed, it does not appear that any new forms of curves deduced from this general principle are likely to adapt themselves in practice so well as those commonly adopted.

There is also one curve highly applicable in practice, the importance of which requires that it be noticed as a separate principle, which may be thus stated:

The teeth of two wheels will also work truly together, if their acting surfaces coincide with curves traced out by the extremity of a flexible line, unwinding from the circumference of a circle, and called the *involute* of that circle, provided the circles, of which the bounding curves of the teeth are respectively portions, be concentric with the pitch circles of the wheels, and have their radii in the same ratio as the pitch circles.



2040.

Thus, let there be two centres of rotation, A and B, Fig. 2040, of which A T and B T are the primitive radii; through the point T draw any straight line D E; through the points A and B draw the perpendiculars A D and B E, and describe circles from the points A and B as centres, with these lines as radii. Again, let K T H be the involute of a portion of the circle A D, traced by the (flexible) line D T, and this line is manifestly a normal to that curve at T; this point will also be that at which the second curve, traced by E T, the line touches the first. But suppose the circle A D to turn on its centre, and taking with it the curve K T H, the line D E will be a constant normal to that curve, in all its positions; and consequently also to the conducting curve in all *its* positions, and at the same point. Now this property of a curve, of having its normal tangential to a circle, belongs only to the involute of that circle; the conducted curve must therefore be the involute of the circle B E.

As an illustration of this principle, let D E be conceived to represent a band passing round the two circles drawn with the radii D E and A D; the wheels will evidently be driven by this band precisely as they would by the contact of their pitch circles, since the radii of the involute circles have the same ratio as the radii of the pitch circles.

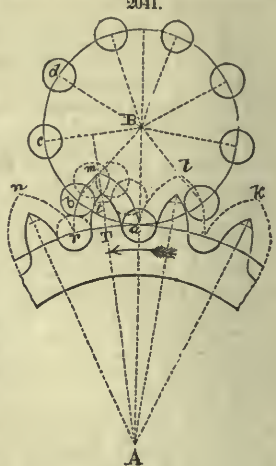
Let it also be supposed, that the projected circles carry round with them their planes as they revolve, and that a tracing point is fixed at any point T of the band; it will trace at the same instant the two curves, and upon both planes, as they revolve beneath it; it is then obvious that these curves, being traced by the same point, must be in contact in all positions of the circles when driven by the band, and therefore when driven by their mutual contact. The wheels would therefore be driven by the contact of teeth of the forms of the curves thus traced by the point T of the band, precisely as they would by the contact of their pitch circles; and it is easy to see that the curves H T K and F T G, so described, are involutes of the circles drawn with the radii A D and B E, from the given centres.

A particular property of teeth formed according to the principle here pointed out, is that they transmit the pressure without altering its intensity—this being the same when we suppose the force constantly applied at the pitch circles, but not at the points of contact of the teeth. In epicycloidal teeth the normal to the curves is variable, as may be seen from Fig. 2029. Thus the pressure at the pitch circles being constant, may be expressed by A c, while that upon the points of contact of the teeth will be expressed by A t, which manifestly varies with the direction of the normal $c\,t$, and consequently with the position of the points of contact of the teeth. Such variation does not occur when the teeth are of the involute form; for then the relation of A D to B E, Fig. 2040, is invariable, since the constant line D E is always normal to the curves in contact; and hence it is obvious that the pressure transmitted from the one circle to the other at D and E has always the same value.

An advantage of this form of teeth is, that if the distance of the centres A and B be altered, but so that the involutes still remain in contact, the velocity of the pitch circles of the wheels will not be affected, and therefore the angular motion of the curves in contact will remain unaltered. This is a property which distinguishes the involute from the other curves that have been given, and is of some practical importance; for, in a pair of wheels of which the teeth are of that form, it is not only unnecessary to fix the centres at a precise distance, but a derangement of the centres, from wearing of the journals and brasses, or settlement of the framework, does not impair the action of the teeth.

It may also be observed, that for every pair of pitch circles an infinite number of pairs of involutes may be assigned that will answer the required conditions; for the inclination of E T D to the line of centres is manifestly arbitrary, and every change of inclination manifestly produces a new pair of base-circles, and of involutes to these circles.

2041.



Of epicycloidal teeth.—The simplest illustration of the action of epicycloidal teeth, is when they are employed to drive a trundle, as represented in Fig. 2041. In the first place, let it be assumed, that the staves of the trundle have no sensible thickness; that the distance of their centres apart, that is, their *pitch*, and also their distance from the centre of the trundle, that is, their pitch circle, are known. The pitch circles of the trundle and wheel being then drawn from their respective centres B and A, set off the pitches upon these circumferences, corresponding to the number of teeth in the wheel and number of staves in the trundle; let five pins, *a b c*, &c., be fixed into the pitch circle of the trundle to represent the staves, and let a series of epicycloidal arcs be traced with a describing circle, equal in diameter to the radius of the pitch circle of the trundle, and meeting in the points *k l m n*, &c., alternately from right and left. If new motion be given to the wheel in the direction of the arrow, then the curved face *m r* will press against the pin *b*, and move it in the same direction; but as the motion continues, the pin will slide upwards till it reaches *m*, when the tooth and pin will quite contact. Before this happens, the next pin *a* will have come into contact with the face *a l* of the next tooth, which repeating the same action will bring the succeeding pair into contact; and so on continually.

We have here assumed the pins to represent the staves of the trundle and to be without sensible thickness, which is not true in practice. To allow, therefore, of the required thickness of staves, it is manifestly necessary and sufficient to diminish the size of the teeth of the wheel, by a quantity equal to the radius of the staves, sometimes increased by a certain fraction of the pitch for clearance, in this case termed *backlash*. This may readily be done by drawing within the primary epicycloids at the required distance, another series of curves parallel to these. For example, let it be required to draw the proper tooth to impel a stave of the radius *b t*; with that radius *plus* the requisite amount of clearance in the compasses, draw a series of small arcs *from* and *within* the original curve, then a curve touching all the arcs so drawn will be the epicycloid required; this curve acting upon the stave will fulfil the condition stated, for being symmetrical with the first, which passes through the axis of the stave, it will act similarly at its circumference.

In practice, a portion must be cut from the points of the teeth, and also a space must be cut out within the pitch circle of the driver, to allow the staves to pass; but as the sides of these parts never come into contact with the staves, no particular form is requisite; the condition to be attended to is simply to allow of sufficient space for the staves to pass without contact.

We have here supposed the wheel to be the driver, and this being the case, it is evident that the staves being indefinitely small, the contact of the tooth will begin at the instant its base reaches the line of centres at *a*; and during the action of the tooth the point of contact will gradually slide upwards, remaining always in the pitch circle of the trundle, at the same time it recedes from the line of centres, until the contact is finally terminated at the point of the tooth. If the trundle be made the driver, the pitch lines of the pair will still move with the same uniform angular velocity; but the reverse of the preceding action will take place, for in that case the contact would commence at the top of the teeth and cease at their base; it would moreover commence before the line of centres, and terminate when it had reached the point of intersection of that line. Now the friction which takes place between teeth whose point of contact *is approaching* the line of centres, is of a much more injurious character than that which happens while the points of contact are receding from it. Not only does it cause much more friction and vibration, in consequence of the inequalities of the surfaces in contact—and the surfaces even of the most highly-polished bodies have some inequalities, which, when pressed together, interlace —but the teeth at the same time tend to force the axes of the wheels outwards, and very speedily induces injurious effects upon the journals, and also upon the planes of the teeth. When the action is receding from the line of centres the friction is less intense, and its effects less injurious; it tends to draw the axes together, and induces much less vibratory action of the geering.

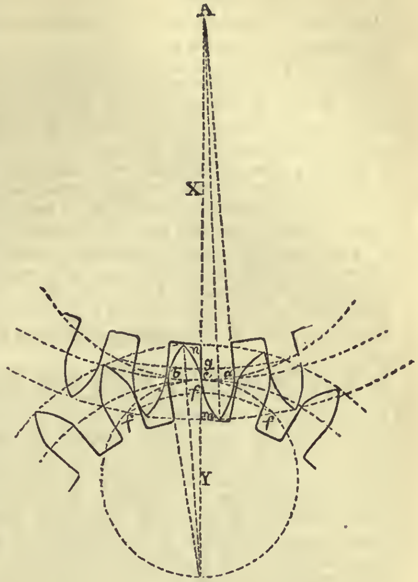
For these reasons it is studied in practice to avoid as much as possible the kind of contact which takes place before the line of centres, by making the wheel the driver and the trundle the follower. The diameter of the staves is also commonly made equal to that of the teeth, with an allowance of a teeth of the pitch for clearance; the radius is therefore rather less than a quarter of the pitch, consequently the contact will begin, the wheel being the driver, when the centre of the stave reaches the line of centres, and therefore at a distance before that line equal to the radius of the stave, or rather less than a quarter of the pitch.

It is also evident that since one tooth must not quit contact before the succeeding tooth is engaged, that when the point *a* has reached the line of centres the tooth T must not have quitted contact with the stave *b*, and the point at which contact ceases must therefore be at an angular distance from the line of centres equal at least to half the distance *a r*, that is, to half the pitch. In a pair of this kind, the action which takes place before the line of centres is less than a half of that which takes place after passing it.

The action of a wheel and trundle being understood, it is easy to comprehend that of the teeth of a pair of wheels of the ordinary construction. Let A and B of Fig. 2042 be respectively the centres of a

wheel and pinion of which the teeth are intended to be of the epicycloidal form, and A c and B c their primitive radii. To lay off the teeth of this pair, having determined the pitch and number of teeth in the wheel and pinion, let the pitch lines be divided into as many equal parts, setting out from the point of contact c, as there are teeth in them respectively. Let the thickness of the teeth be next set off, taking $c\,a$ for the thickness of a tooth of the wheel, and $c\,b$ for that of a tooth of the pinion. Upon the radii A c and B c as diameters, describe two circles, having also their point of contact at c and their centres X and Y. Now let the circle Y be made to roll upon the pitch line of the wheel, and a point io its circumference at c will describe the epicycloidal arc $c\,m$, and this curve determines the form of the point of the tooth of the wheel. In the same way describe the epicycloidal arc $c\,n$ by making the circle X to roll upon the pitch circle of the pinion, and this curve will determine the form of the part of the tooth of the pinion beyond the pitch line.

2042.



Again, the teeth must have the same form on both sides; in other words, they must be symmetrical in reference to the radius which passes through the middle of their thickness, in order that the wheel and pinion may be turned in either direction. If, then, through a point equidistant from c and a and from the centre A of the wheel, a right line be drawn as the axis of the tooth, it limits at m the outline of the tooth; to complete the form of the addendum, it therefore only remains to describe the opposite epicycloidal arc $a\,m$ equal to $c\,m$. A similar process completes the form of the addendum of the pinion.

The curve $c\,m$ of the tooth of the wheel is constantly in contact with the radius B c, and its point of contact is at the same time situated in the circumference of the circle X; the contact will therefore cease when the extremity m of the tooth becomes the point of contact; and this occurs when the point m has arrived at the circumference of Y. If, then, an arc of a circle be described from the centre A with the radius A m, its point f of intersection with the circumference of Y is that at which the tooth ought to cease to act, to secure uniformity of motion, and at the same instant that another new tooth advances into geer. The determination of the point f limits also the useful length of the flank; for if from B as a centre, with radius B f an arc be described, the part $c\,s$ of the radius c B is that which is in contact with the tooth till it arrives at the position B f; and consequently this is the useful length of the flank of the pinion.

Reasoning in the same manner with respect to the teeth of the wheel, it may be determined, that the useful length of the flank of the tooth $c\,a$ is the portion $c\,g$.

We have yet to find the form of the portions of the teeth within their respective pitch circles, or more properly of the spaces between them. The first condition which presents itself is manifestly that the spaces ought to be sufficiently large to allow the projecting portions of the teeth of the opposite wheel to enter freely between them. To resolve this problem in its most general form, it is necessary to find the curve described by the point m upon the movable plane of the circle of B, the pinion being driven by the wheel A. For practical purposes this is not reckoned a matter of much importance; it is usually considered enough that sufficient space for play be allowed whilst the tooth remains strong enough for its work. As every tooth moves between two flanks, and touches only one of them, the space may be bounded literally by radial lines prolonged towards the centre of the wheel. The bottom of the space being sufficiently removed from the pitch circumference to allow the tops of the teeth of the pinion to pass round without touching them, may be described by arcs of a circle drawn from the centre.

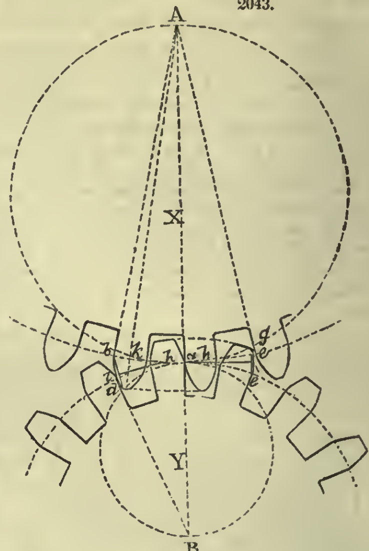
By this arrangement, then, the flanks of the teeth of both wheels of the pair, that is, the portions of the teeth which lie within the respective pitch circles, are radial lines drawn from the centres to the pitch circles, and the faces of the teeth, or those portions which lie without the pitch circles, are arcs of epicycloids traced in each wheel with a describing circle equal in diameter to the pitch radius of the other wheel. Accordingly each flank and face will act in contact to produce a constant angular velocity ratio of the pitch circles of the pair, and the action of each pair of teeth will be confined to its own side of the line of centres.

In practice, and especially when the teeth of the wheels are small, it is not usually considered necessary to apply strictly the form of the epicycloid to find curves of the teeth; but to define them approximately by some such mode as the following.

Referring to Fig. 2043, after having divided the pitch circles into the proper number of parts corresponding to the number of teeth, and set off upon the pitch lines the thicknesses of the teeth, through the extremity b of the pitch $a\,b$ of the pinion, draw a radius B b cutting the circumference of the epicycloidal circle Y in d. Joining the point d with the first division b' of the wheel, draw a perpendicular upon the middle of the line $d\,b'$ meeting the circumference of A at the point h; an arc described from this point as a centre, and with $h\,b$ as a radius, will define the curve of the teeth of the wheel with sufficient exactness.

The length of the teeth is limited at d where the curve of the tooth meets the circumference of the epicycloidal circle Y; for when the tooth has arrived at that point, another pair ought to come int geer at the line of centres. The flank of the tooth being radial, may be defined by a right line from the termination of the curve of the face of the tooth in the pitch circle drawn towards the centre A.

2043.



As the tooth is symmetrical about the axis A k, its opposite face may be described by taking off the form of the side found upon a mould; and the two sides being thus found, a pattern tooth may be formed and used in drawing in the other teeth of the wheel.

A similar process gives the form of the teeth of the pinion. Having taken an arc $a\,e$ equal to the pitch, draw A e till it meets the circumference of X in g; with this join the division e' of the pinion, and through the middle of the line draw a perpendicular, meeting the circumference of Y in h'; from this point as a centre, and with radius $h'\,e'$, describe the curve $g\,e'$, which defines the face of the tooth. A radial line meeting the curve at e' and drawn towards B as a centre, will in like manner define the flank of the tooth.

To determine the bottom of the space between two teeth, it is to be remarked that in the pinion this must be at a distance from the centre A, at least equal to A a; if, therefore, from the point B as a centre, with radius B m, a circle be described, it will define the bottoms of the teeth of the pinion; and in like manner, if with radius A n a circle be described from the centre of the wheel, it will define the bottoms of its teeth. The angles at bottom are commonly rounded, which, at the same time that it improves the appearance, strengthens the teeth.

The forms of the teeth are also occasionally described by arcs, of which the radii are equal to the pitch, and with the centres taken upon the pitch lines.

In this case the centres of these arcs must fall upon the sides of the teeth, which being already marked off, it becomes a simple process to describe the upper portions. This method, which differs little from the preceding, may be conveniently substituted for it, when the diameters of the wheels are not very unequal, and the teeth not thick. But for small pinions, with larger teeth, the first method must be adopted.

In many cases the curves of the teeth are described by arcs drawn from the centres of the adjacent teeth upon the pitch line. This gives a radius equal to the pitch, *plus* half the thickness of a tooth. In like manner, the sides of the teeth also are sometimes described by arcs from the centres of the adjacent teeth giving a radius equal to the pitch, *minus* half the thickness of a tooth.

This form of the tooth may be defective, in the case of a very small pinion having to transmit great pressure, as the extremities of the teeth may be too much reduced. In this case, the curves or faces of the teeth may be described with radii equal to three-fourths of the pitch; and if this be not sufficient curvature, radii equal to some smaller fraction of the pitch may be used.

When, on the contrary, the pitch is large, and the pressure comparatively small, the teeth may be too short; this will be remedied by employing arcs of which the radius is one and a half or twice the pitch. A general method of determining these radii will presently be given.

Another condition which it is necessary to advert to, is the point in the circumference at which contact of the teeth commences. This point is necessarily that in which the two pitch circles cut the line of centres, as may be rendered obvious by reference to Fig. 2042. Here it is plain that the face $c\,m$ of the tooth of the wheel ought to act upon the side of the tooth of the pinion, until the extremity m of the tooth arrives at the extremity of that side, as shown by the position of the tooth f. But were this to take place before the acting surface of the succeeding tooth of the pinion had arrived at the line of centres, the succeeding tooth of the wheel would of necessity act, during the first part of its contact, upon the face of that of the pinion, and continue so to do until it had arrived at the line of centres.

On the other hand, should the extremity of the tooth on arriving at f not immediately cease contact, but only be disengaged when the acting surface of the next tooth of the pinion had arrived at or passed the line of centres, the *face* of that tooth would not be at all acted upon by the tooth of the wheel, and the contact with the flank would be entirely beyond the line of centres. In this case, were the wheel constantly to drive the pinion, the curved faces of the teeth of the latter might be altogether dispensed with, without in any way injuring the equality of action. But the condition assumed does not occur in practice; for, on account of the inequalities which take place in the motion of the wheels, whether arising from inequality in the resistance or of speed in the moving power, the wheel and pinion act upon each other alternately, even when the general movement is continuously in the same direction, a circumstance which cannot be safely neglected in the construction of any system of geering.

When the teeth fall into action *before* the line of centres, they must obviously slide upon each other as they approach that line, and their friction, as in the case of the wheel and trundle, is then much greater than it is after they have passed it, on account of their sliding *inwards* upon each other instead of *outwards*, and against a pressure which is augmented in proportion to the curvature of the acting surfaces. And, moreover, in the contact *after* the line of centres, although there exist inequalities on the acting surfaces, they offer comparatively little obstruction to the sliding of the teeth upon each

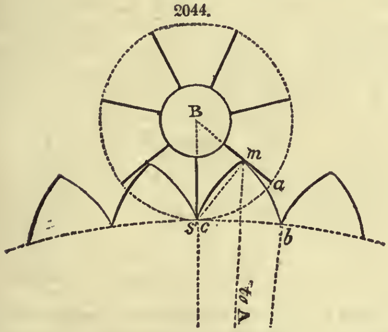
other; whereas, when the contact is in advance, every inequality becomes an abutting obstacle to the *closing in* of the teeth, and which it is necessary to surmount by a species of backward motion at great expense of motive power, and greatly to the detriment of smoothness of motion among the parts of the geering.

But although it is thus clear that an advantage is gained by making the teeth engage after the line of centres, yet this is as clearly desirable only within certain limits. For, as already observed, it is necessary that the tooth of the pinion continue to geer with the wheel until the succeeding tooth has arrived *at* the line of centres—a condition in which is involved the problem of the *minimum* number of teeth that can be given to a pinion to work with a wheel of given size, and which may be determined when the pitch and radii are given. From these data, the angle of the sides of the teeth is immediately deduced. The length and thickness of teeth and width of space must be modified to answer the condition imposed, and the smaller the number of teeth in the pair, the more difficulty there is in accomplishing the solution. To resolve the conditions of the question into the simplest form which they admit, let us take the imaginary case of a pinion of *seven* teeth, without visible thickness, to geer with a wheel of *fifty* epicycloidal teeth, as represented in Fig. 2044. In this the line A B is the line of centres; $c\,m\,b$ one of the teeth of the wheel, and $\mathrm{B}\,m\,a$ one of the radial teeth of the pinion, with which the tooth $c\,m\,b$ has been in contact during its motion from c to b. Now since the pinion has seven radial teeth, the value of the angle $c\,\mathrm{B}\,a$ is $\frac{360}{7}^{\circ} = 51^{\circ}\ 25'\ 43''$; and making the radius $\mathrm{B}\,c = 1$, the right-angled triangle $\mathrm{B}\,m\,c$, completed by drawing the right line $c\,m$, gives,

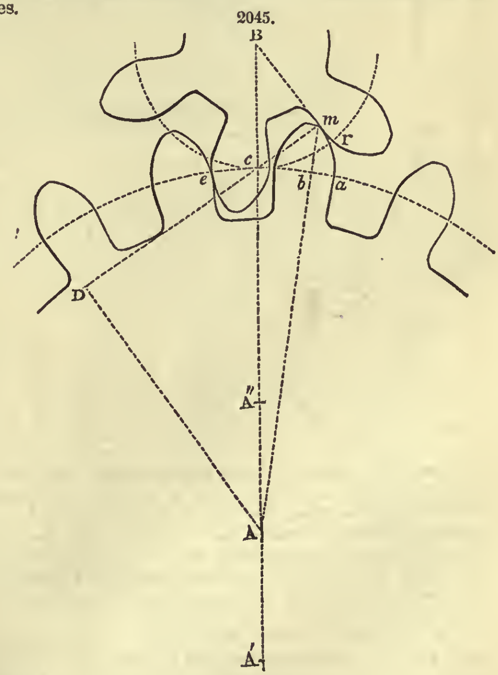
$$\mathrm{B}\,m = \cos\,a\,\mathrm{B}\,c = \cos\,51^{\circ}\ 25'\ 43'' = 0{\cdot}62349.$$

If radius $\mathrm{B}\,c = 1$, then $\mathrm{A}\,c = \frac{50}{7}$ and $\mathrm{A\,B} = \frac{57}{7}$. Thus we have given in the triangle $\mathrm{A}\,m\,\mathrm{B}$ the two sides A B and $\mathrm{B}\,m$ and the angle $a\,\mathrm{B}\,c$; and therefore we have also the angle $\mathrm{B\,A}\,m = 3^{\circ}\ 35'\ 50''$. Now if the wheel have 50 teeth, we have the angle $c\,\mathrm{A}\,b$, containing a tooth and a space, $= \frac{360}{50}^{\circ} = 7^{\circ}\ 12'$; and subtracting from this the angle $c\,\mathrm{A}\,m$, there remains the angle $b\,\mathrm{A}\,m = 3^{\circ}\ 36'\ 10''$; but the angles $b\,\mathrm{A}\,m$ and $m\,\mathrm{A}\,c$ are equal, and by consequence the angle $b\,\mathrm{A}\,c$ is double the former of those that is, $7^{\circ}\ 12'\ 20''$, the tooth being symmetrical in reference to $\mathrm{A}\,m$. Now we found the angular value of the pitch $c\,b = 7^{\circ}\ 12'$, which ought to contain the tooth and the space. It therefore follows that even when the tooth of the pinion has no thickness, it is impossible to place the tooth of the wheel in the pitch interval—for this is shown to be less than the tooth of the wheel would occupy; and it is easy to understand that a wheel of less than 50 teeth could still less be made to drive a pinion of seven teeth. And although in a wheel which has more than 50 teeth the pitch angle would be found greater than the thickness of a tooth, still it would be less than that which should contain the thickness and the space together; hence the angle which would be found due to the space would be so small as to be insufficient to receive the tooth of the pinion, allowing for lateral clearance, and in consequence the pair would necessarily geer *before* the line of centres.

2044.



2045.



This problem is often more conveniently solved organically, when the teeth of the wheel and pinion are formed in the usual manner. Thus in Fig. 2045, let $c\,\mathrm{B}\,m$ be the angle through which it is desired that the contact of the tooth $a\,m$ should continue after passing the line of centres; then as the contact ends at m, the point of contact will be at the extremity m of the tooth. Join $c\,m$ by a right line which will be a perpendicular to the radius $\mathrm{B}\,r$; also join $\mathrm{A}\,m$. Then, since a was in contact with r at the line of

centres, the arc $ca = cr$ is given, and is that portion of the pitch through which the contact of the tooth is required to continue. Then ab is half the thickness of the tooth, *minus* half the base of the portion cut off; and ea is equal to the pitch, and must contain one tooth and the space between. Supposing these qualities to be equal, then since ab contains less than half a tooth, and cannot contain more, eb must contain half a tooth and space at least, and in this case as much more as ab is less than half a tooth. Therefore for every given value of $c\,B\,m$, a value of $c\,A$ may be assigned which shall make eb exactly equal to a space and half a tooth, when the tooth is pointed, and with a corresponding and known increment when the tooth is blunted.

If a greater radius $c\,A'$ be taken, the point b will manifestly fall still nearer a and the tooth may be still more blunted; but if a less radius $c\,A''$ be assumed, then the point b will fall nearer to c, and eb will become too small to contain the space and remaining half tooth; and in this case, if the wheel were set out, it would be found that the epicycloidal arcs on the two sides of the tooth would intersect between m and b, and therefore the tooth would be too short to continue in action through the required arc ca.

This mode of illustration is due to Professor Willis, to whom we are also indebted for the following tables derived organically in the manner described, for spur and annular wheels:—

TABLE I.—For spur wheels, showing the least numbers of teeth that will work with given pinions—Tooth — space.

	No. of teeth in given pinion.	Least number of teeth in the wheel.	
		Wheel driving.	Pinion driving.
Arc of action cr = pitch.	5	impossible.	impossible.
	6	—	176
	7	—	52
	8	—	35
	9	—	27
	10	rack.	23
	11	54	21
	12	30	19
	13	20	18
	14	24	17
	15	17	16
	16	15	—
$cr = \frac{3}{4}$ pitch.	3	impossible.	impossible.
	4	—	35
	5	—	19
	6	—	14
	7	31	12
	8	16	10
	9	12	10
	10	10	10
$cr = \frac{2}{3}$ pitch.	2	impossible.	impossible
	3	—	36
	4	—	15
	5	—	13
	6	20	10
	7	11	9
	8	8	8

TABLE II.—For annular wheels, showing the greatest numbers of teeth that will work with given pinions —Tooth — space.

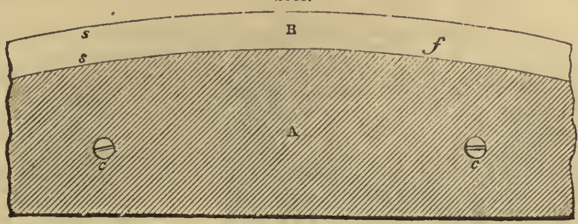
	No. of teeth in pinion.	Greatest number of teeth in annular wheel.	
		Wheel driving.	Pinion driving.
Arc of action cr = pitch.	2	impossible.	5
	3	—	12
	4	—	26
	5	—	85
	7	14	any number
	8	25	—
	9	60	—
$cr = \frac{3}{4}$ pitch.	2	impossible.	10
	3	—	77
	4	5	any number
	5	12	—
	6	77	—
$cr = \frac{2}{3}$ pitch.	2	impossible.	14
	4	8	any number
	5	64	—

These tables contain all the limiting cases under the three suppositions of the arc of action being equal to the pitch, to *three-fourths* of the pitch, and to *two-thirds* of the same. When the arc of action and pitch are the same, the teeth of the follower may be reduced in length to the pitch circle, and the contact of the teeth confined to their recess from the line of centres; when the arc of action is reduced, as in the other two cases given, the reduction will of course indicate the portion of contact which must take place in advance of the line of centres. Thus when $cr = \frac{3}{4}$ and $\frac{2}{3}$ of the pitch, then it is obvious that the contact of the teeth must begin at least $\frac{1}{4}$ and $\frac{1}{3}$ of the pitch respectively before they reach the line of centres.

It also appears from the table, that a smaller pinion may be employed to drive than to follow. Thus when the action begins at the line of centres, the least wheel that can drive a pinion of *eleven* teeth is *fifty-four;* but the same pinion can drive a wheel of *twenty-one* and upwards. Again, nothing less than a rack can drive a pinion of *ten*, but this pinion can drive a wheel of *twenty-three* and upwards. No pinion of less than ten leaves can be driven, but pinions as low as six may be employed to drive any number above those in the table. And lastly, the least pair of equal pinions that will work together is 16. These limits being geometrically exact, and making no allowance for wear, it is better, indeed necessary, in practice, to allow more teeth than the table assigns.

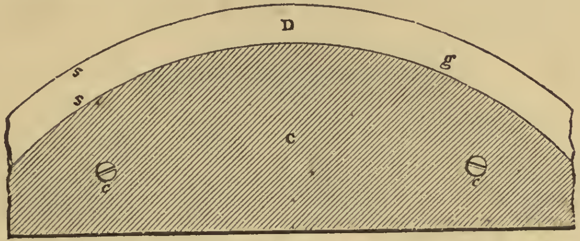
It often occurs in practice that a wheel is required to drive more than one pinion, and *vice versa*, and those of different diameters. In this case the usual mode of obtaining the epicycloidal form of the face of the driving teeth is inapplicable, as that curve is made to depend upon the diameters of the pair when uniformity of motion is studied. But before adverting to the methods by which this condition may be fulfilled, it will relieve us of some of the difficulties of the question to examine the ordinary mode in which epicycloidal teeth are set out. As the workman cannot be expected to be in possession of that accurate mathematical knowledge which would enable him to determine the necessary forms by purely theoretical means, he has recourse to the mechanical method of forming the pattern teeth by *templets.* We give the process in detail.

2046.



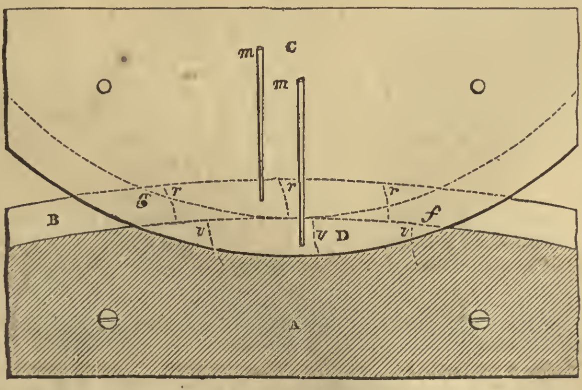
Having determined the pitch of the teeth and the radius of the pitch circle by the methods described, a thin slip of wood—say ⅛ thick—is provided, and on this an arc of the pitch circle is struck. The slip is then cut to the circumference of the circular arc described upon it. Another similar slip is now provided, and on this an arc of a circle equal to the diameter of the wheel to the points of the teeth is in like manner struck, and the edge worked off to the circumference of the circular arc as before. These two pieces so prepared are laid together as in the Fig. 2046; the piece A, whose

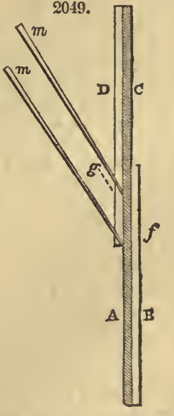
2047.



edge $s f$ is an arc of the pitch circle, is fixing upon B, whose edge is an arc of the extreme circumference of the wheel, the space $s s$ between those edges being in breadth equal to the length of the teeth from the pitch circle to the points. The slips are held firmly in their relative position by two screws c c. This done, a like templet is prepared for the pinion, Fig. 2047; the piece C, whose edge $s g$ is an arc of the pitch circle, is similarly fixed on the piece D, whose edge is an arc of a circle the diameter of which is the *true* diameter of the pinion, the breadth of space $s s$ being, as before, equal to the length of addenda of the teeth.

2048. 2049.



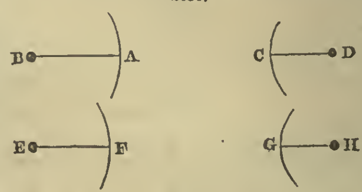


The pair of templets being thus prepared, two tracing points m m are inserted obliquely, and from behind into the piece D of the pinion templet. One of these points passes out at the edge of the piece C, and the other at the edge of the piece D, and the templets are then placed upon each other, as shown in Figs. 2048 and 2049 annexed, so that the circumference of the piece C, that is, the pitch

circumference of the pinion, shall meet the circumference of the piece A, that is, the pitch circumference of the wheel. If in this position the templets be made to roll upon each other through a certain arc, pressing them at the same time slightly together, the tracing points will mark two epicycloidal curves upon the pieces A and B, as *v* and *r*; of these two curves, that marked *v*, which is traced on the face of the piece A, will be the curve of the lower portion or flank, and that marked *r* will be the curve of the upper portion, or face of a tooth of the wheel. If now the thickness of the tooth be marked off on the edge of the piece C, that is, on the pitch circle, and the corresponding tracing point be made to coincide with that point, the curves of the opposite side of the tooth will be formed by making the templets roll together in the contrary direction. A complete outline of a tooth of the wheel is thus described, to which a pattern tooth may be cut and used to shape the teeth by in making the wheel pattern.

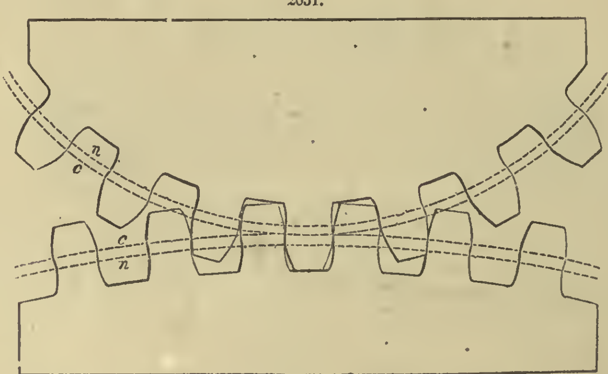
Let now the tracing points be taken out of the pinion templet, and inserted in exactly the same way into the templet of the wheel, and the templets applied to each other as above shown, the operation described will give the outline of a tooth of the pinion upon the parts C and D of the pinion templet.

2050.



Having thus found the curves of the teeth of the pair, pattern teeth may be made and used in setting them out; but this mode is not uniformly adopted. Instead of forming pattern teeth, many prefer to lay off the teeth by circular arcs coinciding approximately with the epicycloidal arcs found by the templets. This is readily done by taking any three points in the curve, and finding the radius with which a circle may be drawn whose circumference will pass through the points so taken, and which will thus of necessity coincide approximately with the normal curve. Radii being found for the curves of the top and bottom of the teeth of the wheel and pinion, their centres are transferred to the circumference of the pitch circles, and circles drawn within these last. Figs. 2050 and 2051 illustrate the process. The arcs B and D, drawn with the radii A B and C D, are those of the face and flank of the wheel tooth; and the arcs F and H, drawn with the radii E F and G H, those of the corresponding off teeth, are drawn from the pitch circles *c c*, Fig. 2051, and parts of the tooth. The pinion curves of the faces in setting those of the flank are drawn from the circles *n n* within the others.

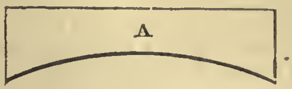
2051.



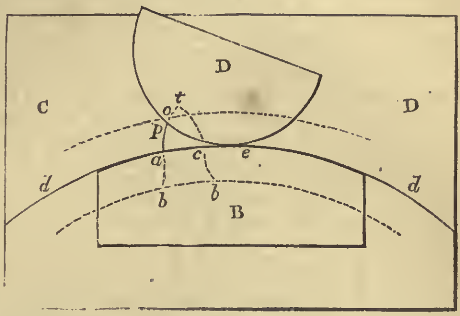
The preceding is a very common mode of obtaining the curves of the teeth of a pair of wheels which are to geer together; but it is faulty, in as far as it gives a form of teeth smaller at the root than at the pitch circles, and also in the circumstance that a pair of wheels set off with templets formed in the manner described, will only work correctly with each other, and not with wheels of any other numbers, although of the same pitch. Thus, a wheel of 30, set off as described, to work with another of 50, will not work correctly with a wheel of 40 or of 60, although the pitch be the same. To effect this it is necessary to employ the proposition already announced and illustrated, and which shows that if there be two pitch circles touching each other, then an epicycloidal tooth formed by causing a given describing circle to roll on the exterior circumference of the one, will work correctly with an interior epicycloid formed by causing the *same* generating circle to roll on the interior circumference of the other. This proposition having been already established, it is unnecessary to dwell upon it further than to observe, that although it has been admitted into the workshop as a fundamental truth, the practice founded upon it does not afford the full advantage which it is adapted to afford, and which might be derived from it by a slight modification of the ordinary practice.

To describe the practical application of the principle, let a thin slip of wood be provided, and let an arc of the pitch circle be struck upon it; divide the slip into two portions through the line of this arc with a fine saw; one part, A, will have a *concave*, and the other, B, a corresponding *convex* circular edge. (Or the same slip may be made with a convex and concave edge of the same radius.) Describe an arc *d d* of the pitch circle upon a second board C D, upon which the pattern tooth is to be drawn. Fix the piece B upon the board, so that its circular edge may accurately coincide with the circumference of the arc *d d*. A portion of a circular plate D is next provided, of the same radius which it is proposed to give to the generating circle: this plate has a fine tracing point at *p* inserted into it, and projecting slightly

from its under surface, and accurately coinciding with its circumference. Having set off the thickness of the tooth *a c* upon the pitch circle *d d*, so that twice this width increased by the clearance which it is desired the teeth should have, may be equal to the pitch, the generating circle D is made to roll upon the convex edge of B; meantime the point at *p* will trace upon the board the curve of the faces of the tooth, having caused the point to coincide successively with the two points *a* and *c*, and the circle to roll from right to left, and *vice versa.*



2052.

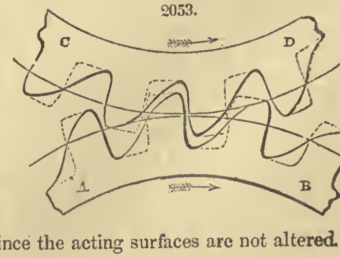


Let the piece B be now removed, and the piece A applied and fixed, so that its concave edge may accurately coincide with the circular arc *d d*; then, with the same circular plate D pressed against the concave edge of A, and made to roll upon it, the point at *p*, which is made as before to coincide successively with the points *a* and *c*, will trace upon the surface of the board C D the two hypocycloidal arcs *a b*, *c b*, which form the flanks of the tooth. The complete tooth, thus formed, has this advantage over the form of tooth found by the former mode, that it will work correctly with the teeth similarly described upon any other wheel, provided the pitch of the teeth be the same, and provided the same generating circle D be used to strike the curves upon the two wheels.

In this manner the general forms of the teeth of the pair are determined. And it only remains to cut them off at such lengths that they shall come into contact in the act of passing through the line of centres. Thus, in Fig. 2042, let Y be the centre of the generating circle of the teeth, then the points *a b*, where the circle intersects the edges of the driving teeth, are the points of contact of the teeth. Now as the teeth ought to come into action only at the line of centres, it is clear that the tooth *f* must have been driven by the tooth of the wheel from the time their contact was at *c*, to which another tooth of the wheel is shown to have advanced, the former being about to quit contact; and since the tooth now advanced to *c* is about to take up the task of impelling the driven wheel, and the other to yield it, it is clear that all the part of the tooth falling within the circumference of the generating circle might be removed; this done, it is evident that all the driving strain would immediately be transferred to the succeeding pair of teeth as required. In order, therefore, to obtain a form of tooth which shall satisfy this condition, by the mode of setting out which has just been described, it is only necessary to take *a c*, in Fig. 2052, equal to the pitch of the tooth, and to bring the circumference of the generating circle D to touch the convex circumference of the arc *d d* in that point: the point of intersection *o* of this circle, with the face *t a*, will be the last acting part of the tooth; and if a circle passing through that point be struck from the centre of the pitch circle, all that portion of the faces of the teeth which lie beyond it may be cut off. The length of the tooth of the wheel intended to act with this may be determined in exactly the same manner. It may, however, happen that the point *o* will fall beyond the point *t* of the tooth; when this occurs, it is then impossible to cut the teeth of such length as to satisfy the condition that they shall drive only after the line of centres. This may be proved organically with a pair of 15 to 15, and other numbers which the preceding table of cases will suggest.

We have here supposed the same generating circle to be used in striking the entire surfaces of the teeth of both wheels. This is convenient, but not essentially necessary; for if the same generating circle be used in striking those parts of the teeth which act together, the required condition will be satisfied. Thus the *flank* of the driving tooth and the *face* of the driven tooth come into actual contact; it is therefore requisite that these curves be respectively an epicycloid and hypocycloid, struck with the same generating circle. And, again, the *face* of the driving tooth and the *flank* of the driven tooth being in contact, these curves must in like manner be struck with the same generating circle. But it is evidently unnecessary that the same generating circle be used in the first and second cases; any generating circle will satisfy the proposed conditions in either case, provided it be the same for the epicycloid and the hypocycloid, which are to act together; observing, however, that as the diameter of the generating circle is increased, the thickness of the root of the teeth will be diminished; and conversely, when made *less* than the radius of the pitch circle, the root of the teeth will spread out, and the curvature of the epicycloidal faces will be proportionally increased, and the teeth shortened. From these observations it is also clear that the forms of the teeth of a pair of wheels which are required to drive continuously in one direction may be so modified as to give additional strength to the teeth without impairing their delicacy of action. Thus, if the wheels represented here, Fig. 2053, the lower A B being the driver, move always in the direction of the arrows, then, instead of the teeth being formed symmetrically, the back of each tooth may be filled up, either by striking the curves by a very small generating circle, or better by involutes, which being proportional to the pitch circles will be sure to clear during the working of the wheels. By this means the strength of the teeth is greatly augmented, as must be obvious, and their action is in no way impaired, since the acting surfaces are not altered.

2053.



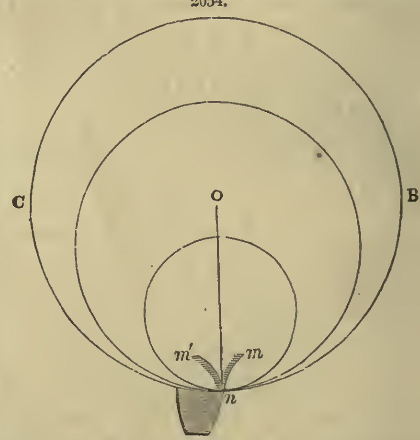
Returning now to the condition often required, though seldom fulfilled in practice, of making wheels of different numbers, when of the same pitch, to work correctly together, it is clear from what has been advanced in connection with the preceding mode of *setting out*, that it is not absolutely necessary to assume the generating circle of any precise radius; it may be taken greater or less within certain limits without affecting the correctness of the working surfaces of the teeth.

Proposition.—"If for a set of wheels of the same pitch, a constant describing circle be taken and employed to trace those portions of the teeth which project beyond each pitch line by rolling on the exterior circumference, and those which lie within by rolling on the interior circumference; then any two wheels of this set will work correctly together."

In illustration of this principle, first announced by Professor Willis, he adduces the established and well-known condition, that the portion of each tooth *within* the pitch line of a driving-wheel works only with the portion which lies beyond the pitch line of the follower, as above shown, and that its action is confined to the approach of the point of contact to the line of centres. After the point of contact of the teeth has passed that line, then the case is reversed, and the portion of the driving tooth which lies *beyond* the pitch line is in contact only with some part of the follower's tooth, which lies *within* its pitch line. Consequently, if a constant describing circle be used for the whole set, it is clear that the proposition will apply to any pair of the wheels, both before and after the teeth have passed the line of centres; for in each case we have an exterior epicycloid working with an interior epicycloid, and both have been drawn by the same describing circle; that is, by the constant circle of the set.

To carry this scheme into practice, it only remains to settle the proper diameter to be given to the describing circle. Let the external circle B C, Fig. 2054, be a pitch circle whose centre is O; then upon this system the flank of the tooth—that is, the portion of it which lies within the circle—will be an arc of an interior epicycloid (or hypocycloid) $m\,n$ or $m'\,n$. Now, if the describing circle be half the diameter of the pitch circle, the flank will become a straight line, coinciding with the radius O n, as shown in Figs. 2042 and 2043. But if the describing circle be of less than half the diameter of the pitch circle, the flank $m\,n$ will be concave, and the base of the tooth will spread; on the contrary, if the describing circle be more than half the diameter, the flank $m'\,n$ will be convex, and the base of the tooth will be contracted inwards—a form manifestly unpractical and useless. It is therefore clear, that the describing circle must not be greater than half the diameter of the pitch line; nor must it be too small, for then the base of the teeth would spread inconveniently, and the curvature of the exterior epicycloids would be injuriously increased, and the teeth become too short. The circle selected should therefore be as large as it can, consistently with the limitation just stated, so that we finally arrive at the practical rule: Make it equal in diameter to the radius of the least pitch circle of the set. And, as pinions should never have less than 12, and if possible not less than 14 teeth, it would be well to establish one of these numbers for that least pitch circle.

2054.



Thus, then, by the use of the same generating circle for all the wheels of the same pitch, they will all work correctly together.

It has already been observed, that, having found the epicycloidal curves of the teeth, by means of the templets, a common method of proceeding is to find, by trial, a centre and small radius, by which the arc of a circle can be described that will coincide nearly with the templet-traced curve. Having found these, as in Fig. 2052, and having struck upon the ends of the rough cogs of his pattern, a circle, concentric with the pitch circle, and whose distance from it is equal to that of the centre of this arc, the workman adjusts his compasses to the small radius, and always keeping one point in the circle just described, he steps with the other to each cog in succession, the cogs having been previously divided into two parts corresponding to the pitch and thickness of the teeth. Upon each cog he describes two arcs, one to the right and the other to the left, which serve him as guides in shaping and finishing the acting surfaces of the teeth. The practical convenience of this method is evinced by the extent of its adoption, and requires only to be aided by a more commodious and certain method of determining the centre and radius of the approximate arc, which has been supplied by Prof. Willis.

But before entering upon the geometrical consideration of the conditions involved, it may simplify the investigation to explain, in the first place, the practical application which Mr. Willis has made of it in the construction of his Odontagraph, an instrument which deserves to be extensively known and understood. The fundamental principle which it involves may be thus exhibited:—

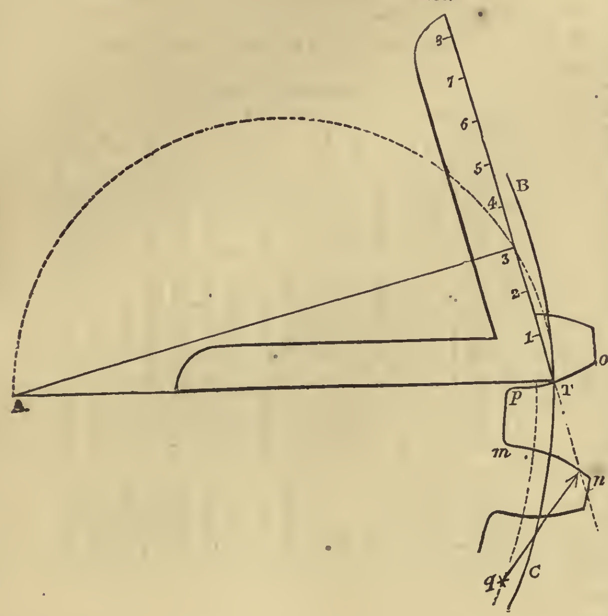
Let A, Fig. 2055, be the centre and A T the radius of the pitch circle of a proposed wheel; draw T 3, making an angle A T 3 $= 75° \; 30'$, with the radius, and drop a perpendicular A 3 upon T 3. Or draw A T, and upon it describe a semicircle, and cut off T 3 $= \frac{1}{4}$ of A T, that is, equal to a quarter of the radius, then will 3 be the centre from which, if an arc $o\,p$ be described through T, that arc will be the side of the tooth required.

This principle being established, it may be adapted conveniently to practice by constructing a bevel of brass, of the requisite form, the angle at T being $75\frac{1}{2}$ degrees: the side T 3 may for convenience be graduated into a scale of quarters of inches as in the Figure; and these divisions may be further subdivided if thought proper. If the bevel so formed be laid upon the radius A T of the proposed wheel and its point T to the pitch circle, the centre point 3 will be found at once by reading off the length of

the radius of the wheel in inches upon the reduced scale. Thus in the figure the radius A T is three inches long, and the point 3 is found at 3 of the scale.

To draw the curves of the other teeth, describe from centre A with radius A 3 the circle *p q*, dotted in Fig. 2055, and falling within the pitch circle; this will be the locus of the centres of the teeth. Thus having divided the pitch circle into arcs corresponding to the pitch of the teeth, take the constant radius 3 T in the compasses, and keeping one point in the dotted circle as at *q*, step from tooth to tooth, describing successively the arcs of the faces first to the right and then to the left. For example, *m n* is described from centre *q*, and *p o* from P.

2055.



The sides of teeth thus formed, consisting each of a single arc, bear considerable analogy to involute teeth, and like these have the fault of acting together with rather too much obliquity; but the mode of describing them is exceedingly simple, and they have this advantage, that they will work correctly with wheels of any number of teeth, with any amount of clearance, and without any great nicety of adjustment of the pitch circles. For wheels of a small pitch—as ¾ inch and under—this mode of setting out may be adopted without risk; but when the sides of the teeth consist of single arcs, there can only be one position of action in which the angular velocity will be strictly constant—and that is when the point of contact is on the line of centres. This objection is obviated by making the side of each tooth to consist of *two arcs*, joined at the pitch line, and so struck that the point of action of the one shall be a little before the line of centres—say at the distance of half the pitch; and the exact point of the other at the same distance beyond that line.

The mode of drawing these arcs is very fully described by Professor Willis, but it is much too complex to be rendered available in the workshop; besides, it has been rendered superfluous for practical purposes by his Odontagraph, in which it is embodied. This instrument, which is fast coming into use, is usually formed of card-paper, sheet-brass, or plane-tree. Fig. 2056, as constructed by Messrs. Holtzapffel and Co., of London, contains within it the requisite tables of numbers.

One side is graduated into a scale of half inches, each half inch being again subdivided into ten equal parts. The line *t* D, which corresponds to the radius of the wheel, makes an angle of 75° with the side. The mode of using the instrument is thus explained in its application to the setting out of a wheel of 29 teeth of 3-inch pitch.

Describe an arc of the required pitch circle, and upon it set off the pitch T *t*, Fig. 2057; bisect this in *c*, and draw radial lines B T and B *t*. For the arc within the pitch circle apply the slant edge of the scale to the radial line B *t*, placing its extremity *t* on the pitch circle as in the Fig. In the table headed *Centres for the Flanks of the Teeth*, look down the column of 3-inch pitch, and opposite to 30 teeth—which is the nearest number to that required—will be found the number 49. The point *r* indicated on the drawing board by the position of this number on the scale of parts marked "*Scale of centres of Teeth* within the *Pitch Circle*," is the centre required, from which the arc *e f* must be drawn with a radius *r e*.

The centre for the arc *d e*, which lies outside the pitch, is found in a manner precisely similar, by applying the slant edge of the scale to the radial line B T. The number 21 obtained from the table of *Centres* for *the Faces of the Teeth*, will indicate the position of this centre upon the scale of *Centres for Teeth outside the Pitch Circle*, namely, at R.

2056.

THE ODONTAGRAPH.

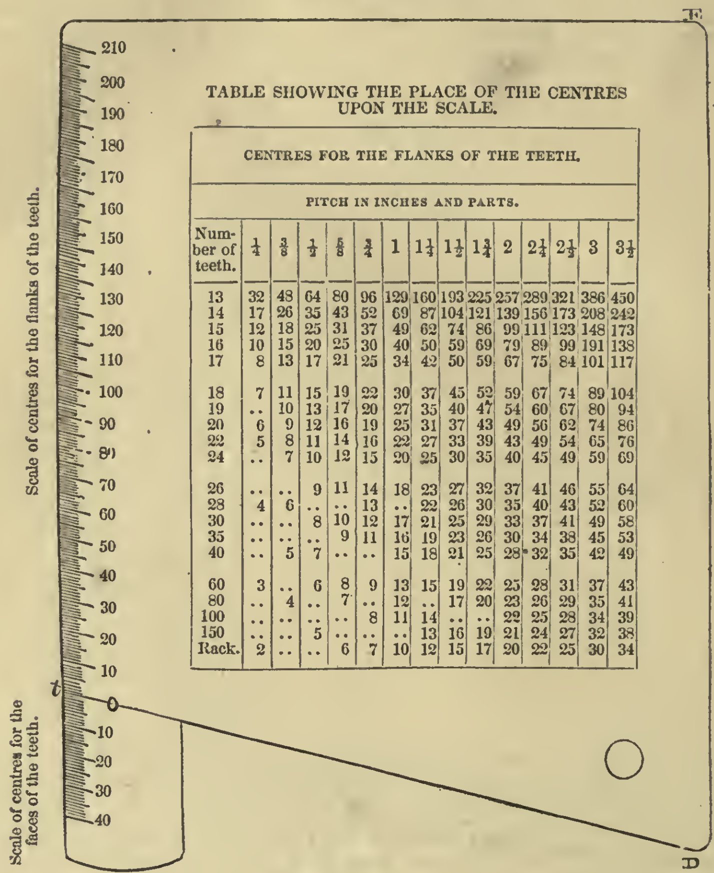


TABLE SHOWING THE PLACE OF THE CENTRES UPON THE SCALE.

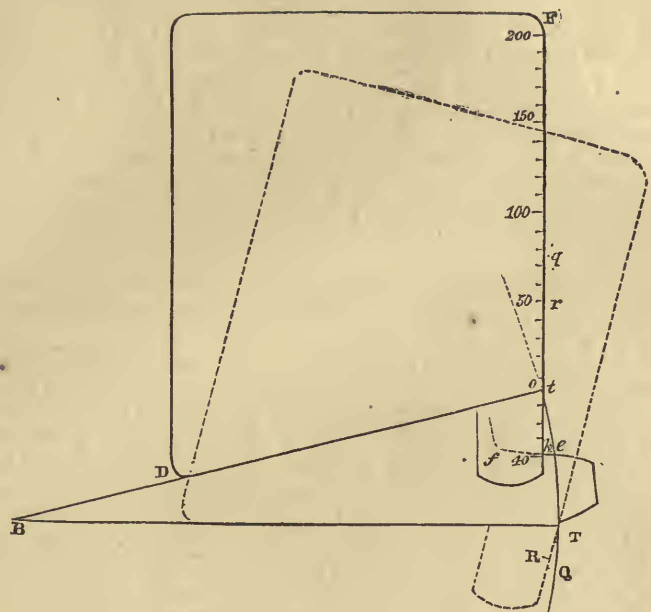
CENTRES FOR THE FLANKS OF THE TEETH.														
PITCH IN INCHES AND PARTS.														
Number of teeth.	¼	⅜	½	⅝	¾	1	1¼	1½	1¾	2	2¼	2½	3	3½
13	32	48	64	80	96	129	160	193	225	257	289	321	386	450
14	17	26	35	43	52	69	87	104	121	139	156	173	208	242
15	12	18	25	31	37	49	62	74	86	99	111	123	148	173
16	10	15	20	25	30	40	50	59	69	79	89	99	191	138
17	8	13	17	21	25	34	42	50	59	67	75	84	101	117
18	7	11	15	19	22	30	37	45	52	59	67	74	89	104
19	..	10	13	17	20	27	35	40	47	54	60	67	80	94
20	6	9	12	16	19	25	31	37	43	49	56	62	74	86
22	5	8	11	14	16	22	27	33	39	43	49	54	65	76
24	..	7	10	12	15	20	25	30	35	40	45	49	59	69
26	..	..	9	11	14	18	23	27	32	37	41	46	55	64
28	4	6	..	..	13	..	22	26	30	35	40	43	52	60
30	..	..	8	10	12	17	21	25	29	33	37	41	49	58
35	..	..	..	9	11	16	19	23	26	30	34	38	45	53
40	..	5	7	..	..	15	18	21	25	28	32	35	42	49
60	3	..	6	8	9	13	15	19	22	25	28	31	37	43
80	..	4	..	7	..	12	..	17	20	23	26	29	35	41
100	..	..	..	..	8	11	14	..	..	22	25	28	34	39
150	..	..	5	..	..	..	13	16	19	21	24	27	32	38
Rack.	2	..	..	6	7	10	12	15	17	20	22	25	30	34

TABLE SHOWING THE PLACE OF THE CENTRES UPON THE SCALE.

CENTRES FOR THE FACES OF THE TEETH.														
PITCH IN INCHES AND PARTS.														
Number of teeth.	¼	⅜	½	⅝	¾	1	1¼	1½	1¾	2	2¼	2½	3	3½
12	1	2	2	3	4	5	6	7	9	10	11	12	15	17
15	...	...	3	...	...	...	7	8	10	11	12	14	17	19
20	2	...	...	4	5	6	8	9	11	12	14	15	18	21
30	...	3	4	...	...	7	9	10	12	14	16	18	21	25
40	...	...	...	...	6	8	...	11	13	15	17	19	23	26
60	...	...	...	5	...	...	10	12	14	16	18	20	25	29
80	...	...	...	...	...	9	11	13	15	17	19	21	26	30
100	...	...	...	...	7	...	...	...	...	18	20	22	...	31
150	...	...	5	6	...	...	...	14	16	19	21	23	27	32
Rack.	...	4	...	...	...	10	12	15	17	20	22	25	30	34

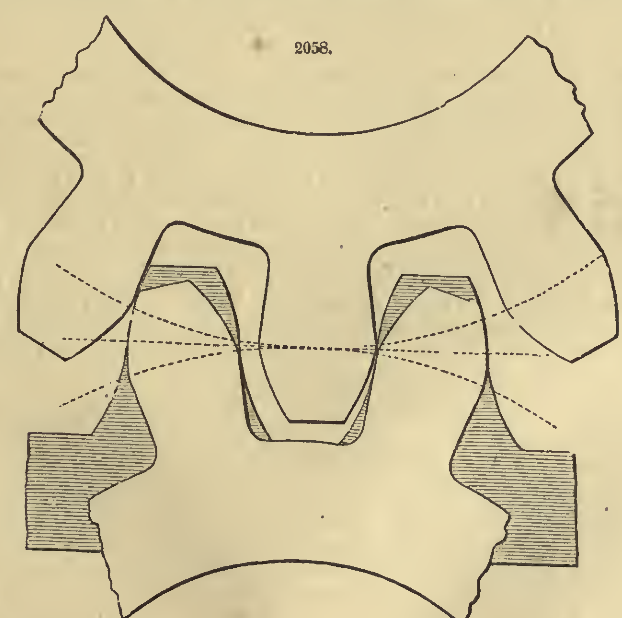
The double curve df is also true for an annular wheel of the same number of teeth, f becoming of course the point of the tooth and d its root. For a *rack* the pitch line T t will be a straight line, and B t, B T, drawn perpendicular to it at a distance from each other, equal to the pitch.

2057.



The numbers for pitches not stated in the table, may be obtained from the column of some other pitch by direct proportion. Thus for 4-inch pitch, by doubling the number of the column of the 2-inch pitch; for 4½ by doubling 2¼, and so on; or if the difference be small, the column belonging to the

2058.



nearest pitch may be employed without a serious error; or more accurately, a number may be taken half-way between those given in the two nearest columns. Also no tabular numbers are given for 12 teeth in the upper table, because within the pitch circle their teeth are radial lines.

In reference to the numbers given in the tables, the inventor observes that it is unnecessary to extend these to every wheel, as the error produced by taking those belonging to the nearest, as above directed, is so small as to be unappreciable in practice.

The difference in form between the tooth of one wheel and of another is due to two causes; the first is the difference of curvature, which is provided for in the Odontagraph, by placing the compasses at the different points of the scale of equal parts; and secondly, the form depends on the variation of the angle T B *t*, Fig. 2057, which is met by placing the instrument upon the two radii in succession.

The first is the only cause with which these calculations are concerned. Now in three-inch pitch, the greatest difference of form produced by mere curvature in the portion of tooth which lies beyond the pitch circle, is only 1-25th of an inch between the extreme cases of a pinion of 12 teeth and of a rack; and in the acting part of the arc within the pitch circle it is 1-10th of an inch; so that as all the other forms lie between those two, it is clear that if we select only four or five examples for the outer side of the tooth, and ten or twelve for the inner side, we can never incur a greater error than the $\frac{1}{200}$ part of an inch, in a three-inch pitch, by always taking the nearest number in the manner directed, and a proportionally smaller error in smaller pitches. But to insure this, the numbers ought to be so taken, that the corresponding form shall lie equally between the extremes. This is more necessary with wheels of small numbers of teeth, since the variation of form is much greater among the teeth of low than among those of larger number.

Fig. 2058 shows the relation of the curves of the teeth of a rack and pinion of 12 teeth, both adapted to work into the same wheel. They are drawn with accuracy, and on a large scale, so as to afford a graphical comparison of the two extreme cases.

The Odontagraph is likewise applied to determine the correct form for *cutters* used in the wheel-cutting machine, for shaping the teeth of metal and cog wheels. The form of the cutter is manifestly that of the space between two contiguous teeth; and may therefore be determined by drawing a pair of teeth in any particular case. But in making a set of cutters especially for small pitches, it is not by any means necessary to make one for every number. The forms for numbers of teeth that lie closely together are, as already remarked, very nearly alike—so nearly alike indeed, that the errors of workmanship would entirely destroy the difference, particularly when the numbers are high. When the numbers are very low, there is less room for deviation from the strict rule—not more, for example, between the form of a cutter for 16 and 17, than there is for a cutter for a wheel of 150 teeth and another for one of 300. This being the case, it appeared to Mr. Willis to be worth while to investigate some rule by which the necessary cutters could be determined for a set of wheels, so as to incur the least chance of error; and to this effect he has calculated, by a method sufficiently accurate for the purpose, the following series of what may be termed equidistant values of cutters; that is, a table of cutters so arranged that the same difference of form exists between any two consecutive numbers.

TABLE OF EQUIDISTANT VALUES FOR CUTTERS.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of teeth.	Rack.	300	150	100	76	60	50	43	38	34	30	27	25	23	21	20	19	17	16	×	15	14	13	×	12

This table affords the requisite information in the selection of the wheel to which each cutter shall be accurately adapted, after it has been determined how many are necessary in a set. For example, if a single cutter were thought sufficient for a set of very small wheels, it had better be accurately adapted to teeth of 25, for that value is intermediate between the two extremes. If three cutters are to suffice for the whole set, then 76, 25, and 15 ought to be selected—of which the cutter 76 may be used for all teeth from a rack to 38; the cutter 25 from 38 to 19, and the cutter 15 from 19 to 12; and so on. In cutters, the greatest difference of form is at the apex of the tooth, that is, at the base of the cutter, and this amounts to $\frac{1}{4}$ of an inch in 2-inch pitch, when the teeth have the usual addendum. From this the difference for any smaller pitch may be ascertained, and as many cutters interposed as the workman's notion of his own powers of accuracy may induce him to think necessary. Thus, if the hundredth of an inch be his limit of accuracy in forming his cutters, and he proposes to make a set for half-inch pitch, where the difference of form is $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$, that is, $\frac{6}{100}$ nearly, then half a dozen cutters will be sufficient, and these must be made as nearly as possible to suit the wheels 150, 50, 30, 21, 16, 13.

The following table contains a selection of numbers for different cases which may save trouble:—

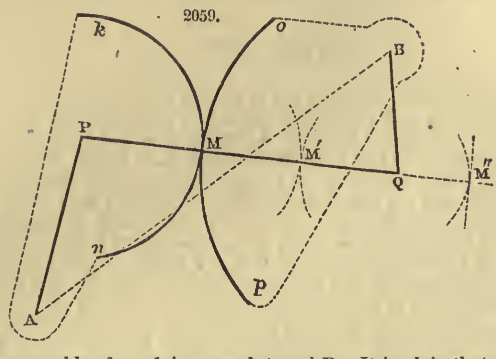
TABLE OF CUTTERS.

No. of cutters in the set.	Numbers of Teeth to be selected.																							
2	50	16																						
3	75	25	15																					
4	100	34	20	14																				
6	150	50	30	21	16	13																		
8	200	67	40	29	22	18	15	13																
10	200	77	50	35	27	22	19	16	14	13														
12	300	100	60	43	34	27	23	20	17	15	14	13												
18	300	150	100	70	50	40	30	26	24	22	20	18	16	15	14	13	12							
24	rack	300	150	100	76	60	50	43	38	34	30	27	25	23	21	20	19	18	17	16	15	14	13	12

When the numbers have been selected, the Odontagraph may be employed to draw the figure of the cutter corresponding to each wheel, either on the same scale, or better, on a larger scale, which may be afterwards reduced proportionally to the size required.

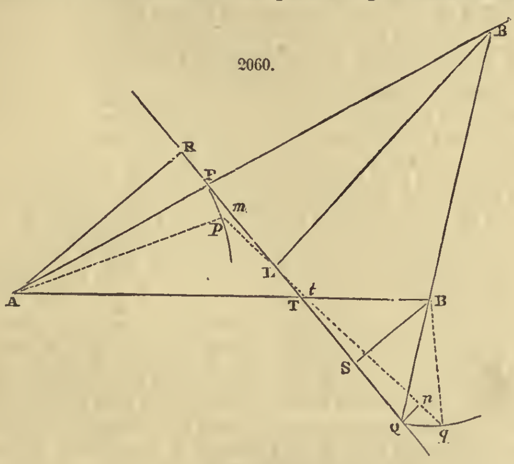
To explain the principle of the Odontagraph, let us, in the first place, observe the action of the two pieces in the annexed diagram, Fig. 2059, of which P and Q are the centres of curvature at the points

2059.



of contact, and which are capable of revolving round A and B. It is plain that the line P Q is, in every position of contact of these curves, equal to the sum of their radii, and must therefore be constant during such motion; and hence, if for the circular arcs, a pair of rods A P, B Q, connected by a link P Q, be substituted, their angular velocity will be to each other as the segmental arcs which they respectively represent, and P Q will be a constant and common normal to their arcs of motion. It is also clear that a change in the actual lengths of the radii will not affect the motion, the distances of the centres being constant. Now let the rod A P be moved into a new position A p, as shown in Fig. 2060; its extremity

2060.



will manifestly carry with it the end of the link P Q, and communicate through it a motion to the arm B Q, causing it to assume likewise a new position B q. It is necessary to know the relative value of this motion to that of A P which produced it, which, though constantly changing, may be thus determined at any instant.

When the rod P Q changes its position, it may be considered during its motion to turn about some centre in space, although the relative position of that centre be perpetually shifting. This centre must of necessity be the point in which the arms A P, B Q would intersect if produced. Thus the momentary centre, when the motion begins, is K. For as the extremity P moves round the centre A, the direction of its motion at starting must be perpendicular to A P, and therefore the momentary centre must be somewhere in the line A P produced. In like manner the initial motion of the extremity Q must be perpendicular to B Q, and the momentary centre must lie somewhere in the direction B Q: but these directions intersect in K, which is therefore the centre in space about which the rod P Q on starting into motion may be conceived to turn. And since the rod P Q turns about K, the direction of motion of P and Q are to each other at any given instant as their radial distances from K; that is, as P K and Q K, which is true whether we consider them as the extremities of the rod P Q or of the radii A P, B Q; also the angular motions of the latter will be found by dividing those direct motions by their radii; that is,

Angular motion of

$$\text{P round A} : \text{angular motion of Q round B} :: \frac{PK}{AP} : \frac{QK}{BQ}.$$

If now we draw K L, A R, B S, then we have

$$
\begin{array}{lll}
PK : AP :: KL : AR & \text{by similar triangles} & KPL ; APR \\
BQ : QK :: BS : KL & \text{- - - - - -} & BQS ; KLQ \\
AT : BT :: AR : BS & \text{- - - - - - -} & ART ; BTS
\end{array}
$$

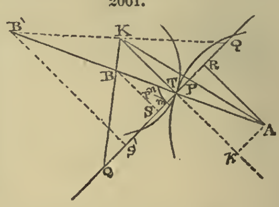
And compounding these three proportions we obtain

$$\frac{PK}{AP} : \frac{QK}{BQ} :: BT : AT$$

that is to say, the angular motion of the arms are to each at any moment inversely as the segments into which the link divides the line A B, joining the centres of motion or *line of centres.* If now the link move into a new position $p\,q$ near the first, and it happen that this second position intersects the first in a point L above or below the line of centres, as shown in the Figure, then the ratio A T : B T will be changed into A t : B t, and consequently the angular motion will be an increasing or decreasing ratio. But if the point L coincide with the line of centres, this ratio for the moment will remain constant.

Now, a little consideration will show that the point of intersection between two successive positions P Q, $p\,q$ of the link must be at the place where the perpendicular from K falls upon it. For as K is the momentary centre of motion, the extremity L of the perpendicular will begin to move in line at right angles with it, and consequently will remain in the direction of the first position when the link has passed into the second position; in other words, it will be in the point of intersection of the two positions. When, therefore, the rods are in such a position that the perpendicular from K meets the link P Q in the line of centres, the ratio of the angular motions of A P and B Q is constant; and if in this state the points P and Q be employed as centres whence short arcs are drawn through any common point M′, as in Fig. 2059, and applied as teeth, these arcs will manifestly drive each other correctly when in the exact relative position described, and very nearly so when removed to a short distance on either side of it, which is the thing required.

2061.



Now these relative positions of P and Q may be determined by a simple construction founded upon the necessary coincidence of L and T. Thus let A and B, Fig. 2061, be the centres of a pair of wheels, and A B the line of centres divided at T, the point of contact of the pitch circles. Draw P T Q, making any angle with the line of centres, and upon it assume P as a centre from whence the circular side is to be described of a tooth of the wheel whose centre of motion is A. To find the corresponding centre for a tooth of the wheel which turns upon B, draw T K perpendicular to P Q, produce A P to meet it in K; join K B and produce it to meet P Q in Q, then will Q be the required centre—as will appear by comparing Fig. 2061 with Fig. 2060. If then a small arc $m\,n$ struck from P be taken as the face of a tooth of the wheel on A, it will work correctly with an arc $m\,p$ struck from Q through m, and employed as a tooth of the wheel on B.

Were B Q so taken as to make the angle K B T acute—for example at B′, then would Q fall at Q′ on the same side of T as P, but beyond it, and the effect would be that the tooth $m\,p$ would be concave instead of convex. And if the angle K B T = P T A, then will K B become parallel to P T, and the point Q being thus removed to an infinite distance, the arc $m\,p$ of the tooth of the wheel on B will be a right line perpendicular to P T.

The angle A T P is arbitrary, and its value may, therefore, be determined from other conditions than those stated. It may be remarked, however, that if made a right angle, the points P and Q will vanish by coinciding with T; and if it be made a little less than a right angle, the points P and Q will be thrown so near to T, that the radii by which the arcs are struck become too short, and the points of the teeth too much rounded off. On the other hand, if the angle A T P be made too acute, the action of the teeth upon each other at the moment of passing the line of centres and elsewhere becomes very oblique, and an injurious pressure is thereby thrown upon the axis of the wheels. By various trials Mr. Willis has adopted 75° as the value of the angle which appears to avoid these extremes, and he has accordingly employed it in the construction of his Odontagraph.

Again, the position of the point m, through which the arcs are to be struck, is also arbitrary, and must be determined by considering which point of the action we wish to make the correct point. If the teeth consist of a single arc each, the correct point may be fixed at the moment of passing the line of centres, and therefore the arcs must be struck through the point T; but if the side of the tooth be formed of two arcs joined, one lying within and the other beyond the pitch line, then the action of one of them will be confined to the approach of the point of contact of the teeth and the line of centres, and the action of the other to its recess from that line, and m must be assumed upon such a principle that the correct point of each arc shall fall nearly in the middle of its action.

The distance between the centres may also be found by calculation, thus: A R being perpendicular to P T, we have by the similar triangles A R P; P T K

$$KT = \frac{PT \times AR}{PR} = \frac{PT \times AR}{TR - PT}$$

$$= \frac{PT \cdot AT \cdot \sin ATP}{AT \cdot \cos ATP - PT}$$

$$\text{therefore } PT = \frac{AT \cdot KT \cdot \cos ATP}{KT + AT \cdot \sin ATP} = D$$

which is the centre for the arc $m\,n$. And similarly drawing B S perpendicular to T Q we have for the corresponding arc $m\,p$.

$$\mathrm{Q\,T} = \frac{\mathrm{B\,T\,.\,K\,T\,.\,\cos A\,T\,P}}{\mathrm{K\,T + B\,T\,\sin A\,T\,P}} = d$$

Now the point P being obtained from the point K on the opposite point of T to A, these formulæ belong to that part of the tooth of the lower wheel beyond the pitch line and the flank of the tooth of the upper wheel. The corresponding face of the upper and flank of the lower wheel may be determined in a similar manner, by joining B k and following the course of reasoning stated for the point K.

In these formulæ, the values of P T and Q T may be determined for any forms of teeth, and also for a set of wheels which shall work correctly together. But the greatest value which in this last case can be correctly assigned to K T must be one which, if r be the smallest radius, shall make

$$\mathrm{K\,T} = r \sin \mathrm{A\,T\,P}$$

Consequently, putting R for the radius of the wheel, and angle $\mathrm{A\,T\,P} = \theta$ the values of D and d, that is, the distances of the centre points of the arcs measured from T, will become

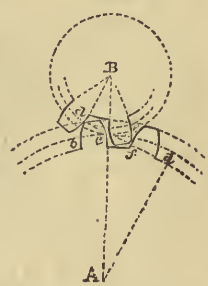
$$\mathrm{D} = \frac{\mathrm{R}\,.\,r\,.\,\cos\theta}{\mathrm{R}+r} \qquad\qquad d = \frac{\mathrm{R}\,.\,r\,.\,\cos\theta}{\mathrm{R}-r}$$

By assuming constant values of r and θ in a set of wheels, the values of D and d which correspond to different numbers and pitches may be calculated and arranged in tables for use. In this way the tables which accompany the diagram of the Odontagraph were obtained by taking the least number of teeth to be given to a wheel $= 12$ and $\theta = 75°$, the numbers being expressed in twentieths of an inch.

In this way these tables may be extended at pleasure, and for any values of r and θ; and perhaps it would be preferable in the construction of such tables to express the numbers in inches and 32ds of an inch, which would better adapt them to the common foot-rule.

Involute teeth.—Involute teeth have the disadvantage, already stated, of being, when in contact, too much inclined to the radius, by which an undue pressure is transferred to their axes. Their mutual friction is thereby little affected, but that of the axes is increased, and their journals are more speedily worn. But they have at the same time the advantage of working with more accuracy under derangement and incorrectness of fitting, and any pairs of them will work truly together in sets within certain limits, however different in diameters, the pitch being the same. Until Professor Willis had developed the mode of adapting the epicycloid to the condition in question, the involute was the only form known in practice by which the conditions of perfect figure for wheels of any sizes to work smoothly in wheels of any other sizes, could be satisfied.

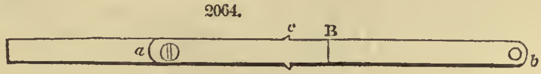
2062.



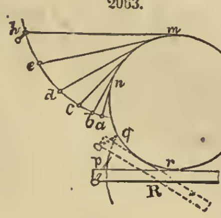
To describe this curve for the teeth of a pair, of which the radii of the pitch circles, and pitch of the teeth are determined, we may employ the mode illustrated by Fig. 2062. Let A and B be the centres of the pair, and $e\,b$ be their pitch lines; join A and B by a right line passing through c; from this last point draw $c\,d$, $c\,d$ perpendicular to the radials B d, A d, and cutting them in d and d; this line $d\,d$ is then a common normal to the teeth in contact, and the perpendiculars A d, B d, are the radii of the involute circles which form the acting faces of the teeth.

The involute curve may be described mechanically in several ways. Thus let A, Fig. 2063, be the centre of a wheel, for which the form of involute teeth is to be found. Let $m.n\,a$ be a thread lapped round its circumference, having a loop-hole at its extremity a; in this fix a pin, with which describe the curve or *involute* $a\,b$ - - - h, by unwinding the thread gradually from the circumference, and this curve will be the proper form for the teeth of a wheel of the given diameter.

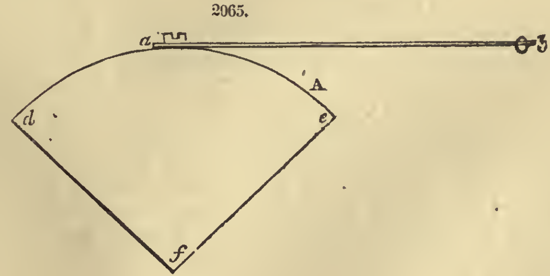
2064.



2063.



2065.



The involute $a\,b$ - - - h may also be produced by an epicycloidal motion; for since the circumference of a generating circle, whose centre is infinitely distant, must be a straight line, we may form the invo-

lute by making a straight ruler roll upon the circumference of the circle to be evolved. Thus let R, in Fig. 2063, be a straight ruler, at whose extremity a pin p is fixed with the point resting upon the point q of the circle; then by rolling the straight ruler upon the circumference, so that the point at which it touches the circle may move gradually from q towards r, the curve $q\,p$ will be generated exactly similar to the involute $a\,b$ - - - - h, and the method is perhaps easier and more accurate than by unlapping a thread from the circumference of the *evolute*, as above described.

Mr. Hawkins, in his Appendix to Camus' Treatise on the Teeth of Wheels, recommends a very simple instrument for striking involute teeth. Two views of this instrument are given in Figs. 2064 and 2065. In these $a\,b$ is a piece of watch-spring, with two teeth $c\,c$, formed upon its edges; at a is a small screw by which the spring is attached to a templet formed of thin board, and equal to a sector of the circle upon which the involute is intended to be generated. At b a small bit of wire is inserted into the spring, to form two knees as a handle by which the spring can be kept stretched. The templet is equal in the thickness to the width of the spring.

In using the instrument, the templet is to be fixed upon the drawing board or surface upon which the involute is to be traced; the centre f coinciding with the axis of the wheel, or its representative on the drawing board; then by holding the knobs b as a handle, and keeping the spring thereby tightly stretched, so that it remains a correct tangent to the circle, and lapping the spring upon the arc of the templet, one of the points c will trace upon the surface over which it passes a curve which, when the point has arrived at the circumference of the pitch circle represented by the templet, will be a true involute of that circle.

If the tracing instrument be now turned over, the opposite tooth c on the side of the spring now undermost, will, by repeating the same operation, trace the counter involute for the other side of the tooth of the wheel.

Mr. Hawkins' mode of proceeding to draw the outlines of a pair of involute wheels with his tracer is simple, and may be explained by reference to Fig. 2062. Having drawn the line of centres A B, and divided it at c into parts A c, B c, proportionate to the intended velocities of the two wheels, next draw the right line $d\,d$ cutting the line of centres at c, and making with it an angle deviating not more than 20 degrees from a right angle. From centre A describe a circle touching the line $d\,d$ at d within the pitch circle of that wheel, and which will thus have $d\,d$ as a tangent at d. In like manner from B as a centre describe a circle touching the same straight line at d within the pitch circle of that wheel, and also having that straight line as a tangent. Then the distance between the two circles is the proper length of the teeth, from which, however, the necessary clearance ought to be deducted. The two circles last drawn are likewise the bases upon which the involutes for forming the boundaries of the teeth are to be generated.

Next, having provided two involute traces made in the way above described, each with a templet corresponding to a sector of the base circle of its wheel, the centre f of the templet is to be applied to the centres A or B of the wheel of the pair to which it belongs, and meeting the points d; then supposing the templet for A to be first used, let it be adjusted until the tracing point c of the spring coincides with some point as d of the base circle of the wheel B, by moving it until it meets the circumference of its own base circle at b, the side $d\,b$ of the tooth $d\,c\,b$ will be formed, and of the proper length, by moving the templet spring over the space included between the exterior of one base circle to the other. By turning over the templet, and adjusting it for the required thickness, the outline of the opposite side of the tooth may be traced in the same manner. Repetition of the operation with the templet of B will give the form of the teeth of that wheel.

If thought desirable all the teeth of the pair may be drawn in the way indicated, or a single tooth of each wheel may be accurately drawn, and two pattern teeth cut to the forms thus found.

Mr. Hawkins states that teeth formed according to this method will communicate equable motion from either wheel to the other, without possessing any tendency to press the shafts outwards—which tendency would exist if the angle of the common tangent ($d\,d$) of the two base circles deviated much more than twenty degrees from a right angle with the line of centres.

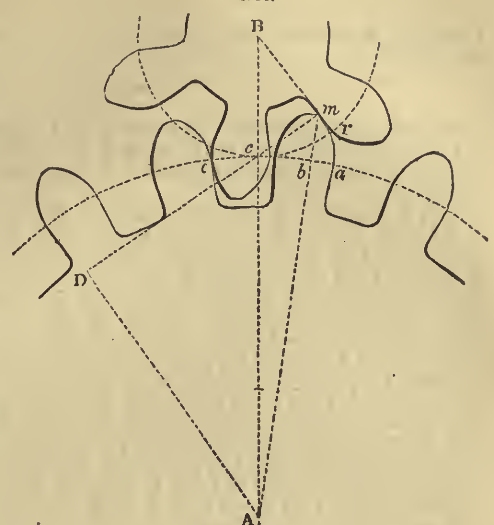
If the teeth of both wheels are to be of equal thickness at the base, which they ought to be when of the same material for the sake of equal strength, the part $d\,f$ of the common tangent ought to be bisected in the middle c of its length, and the involutes drawn in the way described will give the roots of the teeth so nearly equal, that a very slight correction only will be required—the amount depending on the relative diameters of the wheels. But when the teeth of one wheel are required to be thicker than those of the other, the part $d\,f$ of the common normal $d\,d$ must be unequally bisected in proportion to the required difference.

It is finally to be observed that the teeth may have their bases in any other circles than those given, since the radii of the generating circles are entirely arbitrary; but the proportion taken is found to satisfy the conditions required with very little outward action. In respect to the character of the involute curve as compared with the epicycloid, it is obvious that the former possesses the advantage that a greater number of teeth of equal strength may be given to a wheel by this than the epicycloidal form; for with the latter the space must be at least equal to the tooth, while not much more than half the space is required to be marked off on the base circle for an involute tooth of the same length. There are also more teeth engaged at the same time, and thus the strain is divided.

Teeth of a rack and pinion.—A rack, as before observed, may be regarded as a wheel of infinite diameter. The teeth may, therefore, be defined by the epicycloidal method explained for spur-wheels, by making their planks straight, and the teeth of the pinion involutes. Now, the properties which have been shown to belong to involute teeth manifestly obtain, however great may be the dimensions of the pitch circle of their wheels, or whatever disproportion may exist between them. Thus of the two wheels A and B with involute teeth, which work together, let the radius of the pitch circle A c, Fig. 2066, of one become infinite; its circumference will then become a straight line represented by the face of a rack. But whilst the radius A c becomes infinite, the radius A D of the circle from which its involute teeth ar

struck, and which bears a constant ratio to the first, will also become infinite, and therefore the involute $m\,a$ will become a straight line, perpendicular to the pitch line at a. For it is evident that the extremity of a line of infinite length, unwinding itself from the circumference of a circle of infinite diameter, will describe through a finite space a straight line perpendicular to the circumference of the circle. The involute teeth of the rack will, therefore, have their faces perpendicular to the pitch line; and this line will be determined by drawing a tangent to the circle on B through the point of contact from which the involute teeth of the pinion are to be struck. If the radius B m, with which the *involute* circle of the pinion is described, be equal to the radius of its *pitch* circle, the line D m will become parallel to the face of the rack, and the sides of the teeth of the rack perpendicular to it. But in this, while the teeth of one wheel, B, have remained unaltered, and the accuracy of their action uninfluenced by the change in the dimensions of the pitch circle of the other, which has converted it into a rack, and its curved into straight teeth; it therefore follows that straight teeth upon a rack work truly with involute teeth upon a pinion.

2066.

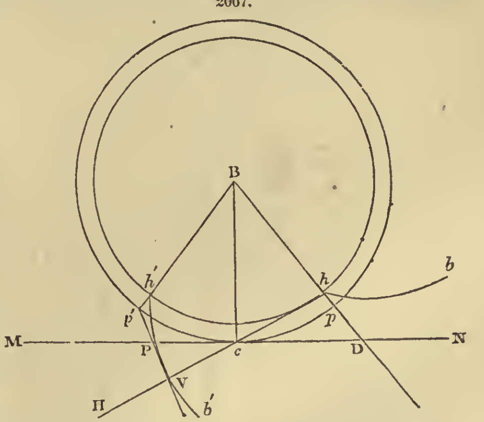


But as straight teeth are not the form of greatest strength which may be attained, and as strength is of importance as well as uniformity of action, the conditions of the problem may be examined with a view to the best modification which the form admits with respect to this test. If with the pitch radius B c of the pinion, Fig. 2067, we describe the pitch circle, and draw M N a tangent to it at c, we next make this right line the pitch line of the rack; and, further, describe the circle whose radius is B h, making this last the base of an involute $h\,b$; then if the tooth of the rack be bounded by a right line k D E, making an angle B D M with the pitch line equal to B $c\,h$, and the involute $h\,b$ be moved into the position $h'\,b'$, it will drive the sloped tooth to the position P m, always touching it in the line $h\,c$ H; and the velocity of the circumference of the pitch circle will always be equal to that of the pitch line.

A wheel with involute teeth will work truly with a rack whose teeth are straight-sided, and inclined to the pitch line at an angle θ, provided only

$$\frac{\text{radius of base}}{\text{radius of pitch circle}} = \frac{\mathrm{B}\,h}{\mathrm{B}\,c} = \sin\theta.$$

2067.



In a rack of this kind, the locus of contact of the teeth being the tangent line h H, the sloping teeth will be pressed downwards by a certain portion of the working pressure, which in some cases may be an advantage in itself by neutralizing vibration, and the advantage of a greatly increased form of teeth is at the same time secured.

The teeth of the pinion being of the regular epicycloidal form, the faces of the teeth of the rack will have a cycloidal form. But according to the usual method of setting out racks and pinions, the pitch line of the rack is the locus of contact, and the action on one side of the line of centres is confined to a constant point in the rack tooth, which is thus subjected to rapid wear. This disadvantage may be abridged by reducing the length of the teeth of the pinion, but it may also be entirely avoided by taking a constant generating circle, and employing it to describe cycloidal flanks for the rack teeth by rolling on its pitch line, and then by describing the faces of the teeth of the pinion with the *same* generating circle, in the manner before described. By this simple modification, the contact will no longer be confined to the pitch line of the rack, but will be distributed over the flanks of its teeth; and these, it may be observed, may be made of any length desired, by regulating the diameter of the generating circle accordingly. If the generating circle have a diameter equal to the radius of the pinion, the flanks of the pinion-teeth will then be radial, and this form may also be modified by taking a circle of greater or less diameter.

To determine the pitch circle of the pinion, let D represent the distance through which the rack is to be moved by each tooth of the pinion, and let these teeth be in number $=$ N; then will the rack be moved through the space N $\times$ D during one complete revolution of the pinion. Now the rack and

pinion are to be driven by the action of their teeth, as they would by the contact of the circumference of the pitch circle of the pinion with the plane face of the rack, so that the space moved through by the rack during one complete revolution of the pinion must precisely equal the circumference of the revolving pitch circle; consequently, calling R the radius of the pitch circle of the pinion, we will have

$$2\pi R = N \times D \quad \therefore R = \frac{N \times D}{2\pi}$$

Two of these quantities being given, the other immediately becomes known. Thus, let D = 2 inches and N = 13, then

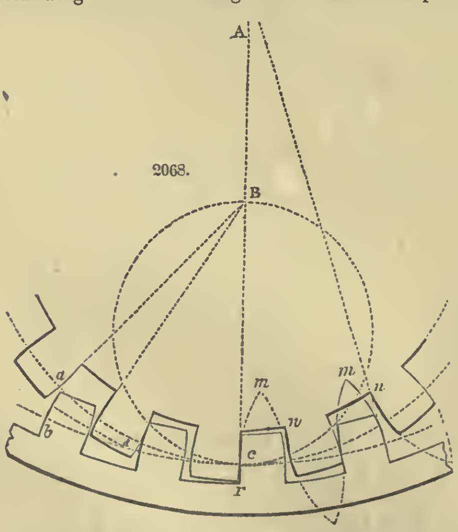
$$R = \frac{26}{2 \times 3{\cdot}1416} = 4{\cdot}138 \text{ inches.}$$

Annular wheel and pinion.—An annular wheel is one having its teeth formed within its periphery and consequently the pinion works internally. In this arrangement, the form of the teeth may be determined according to the principles already explained, with very slight modification in their practical application.

Thus, in Fig. 2068, let A B be the centres of the wheel and pinion; and let *c* be the point of contact of the pitch circles. The epicycloid *c m* described by the circle having a diameter = B *c*, gives the lateral form of the tooth of the wheel, limited as before by a radius drawn to the middle of the thickness of the tooth; and an arc described from the centre B, with radius A *n*, cuts the circumference B *c* at a point which determines the side of the tooth of the pinion at *n*. But if we attempt to apply the same process to finding the face of the tooth of the pinion as we have employed in determining the flank of the wheel-teeth, we shall find that the construction will either not give the side of the tooth as the arcs do not meet, or it will give it a position upon the radius A *c* on the same side as the face *c m*. From this, then, it appears that the teeth of the wheel will have no flanks, and that their outline will consist simply of *faces*. From this it follows that the *pinion* would not drive the wheel uniformly according to the required condition, and in consequence we must find another curve for the faces of the teeth of this last. Now if we trace the epicycloid by a point *c* of the circle to centre A in the figure, rolling it externally upon the circumference of the circle on B, it will give the outline of a tooth capable of fulfilling the condition of uniformity of action at any point of the circumference of the circle on A. Should the teeth engage before the line of centres, the tooth of the wheel would necessarily act constantly at that point and cause great wear, particularly as this species of geering is usually employed in conveying the motion of water-wheels where it is exposed to incessant wetting and vibration.

In practice it is found sufficiently accurate to substitute for the epicycloidal method above described for finding the form of the face of the tooth of the pinion, the more convenient mode of defining it by an arc of a circle drawn from the root of the tooth, with a radius equal to the chord of the pitch.

When the teeth do not engage until they arrive at the line of centres, the faces of the teeth of the pinion may be entirely suppressed, leaving the flanks only, which are alone acted upon by the teeth of the wheel. This may be uniformly done, at least when the pitch of the pinion is small, and when the wheels are more than strong enough for the power which they are required to transmit. In such cases the following method of setting out the teeth of the pair may be adopted with safety.



2068.

2069.

In Fig. 2068, let A be the centre of the wheel, and B the centre of the pinion as before. From the point *c* of contact of the two pitch circles mark off the arcs *c a*, *c b*, equal respectively to the pitch of the pinion and wheel; join *a* B and *b a*, and bisect this last; from the point of bisection raise a perpendicular, and the point *d*, where this meets the pitch circle of the wheel, will be the centre from which the arc *a b*, defining the side of the tooth of the wheel, may be struck. The flank of the tooth of the pinion is determined by the two radii which limit its thickness and meet in B. To define the length of the teeth, it is sufficient to describe a circumference with the radii A *r*, B *n*, leaving sufficient bottom clear

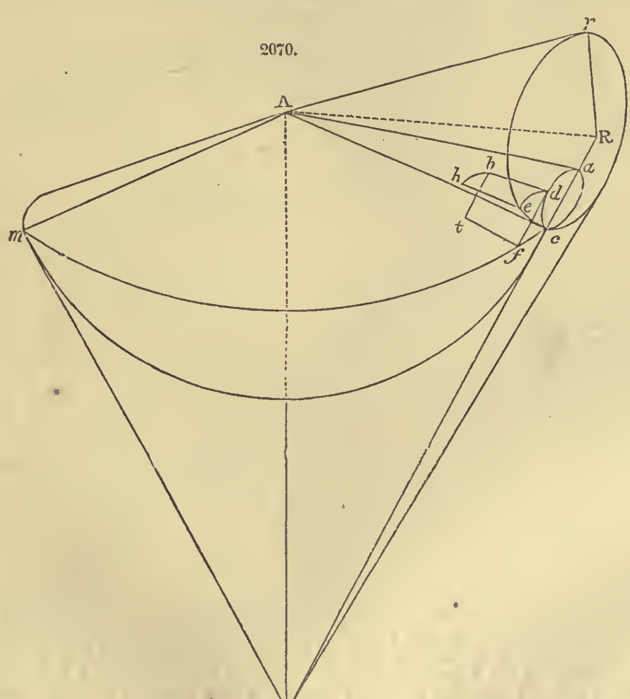
ance; and the extremities of the teeth of the pinion, and the bottoms of those of the wheel, ought to be rounded off by arcs drawn with a radius equal to the chord of the pitch taken upon the pitch circle of the pinion.

By this method it will be seen that the strength of the pinion-teeth is greatly reduced, and ought therefore only to be applied when the power to be transmitted is comparatively light, and when the wheel drives the pinion. It is consequently not recommended for general practice. The epicycloidal method, explained for external wheels, may, on the contrary, be applied in all cases, observing that in the case considered, the *space* answers to the tooth, and conversely, the tooth to the space; so that keeping this distinction in view, the forms of the teeth may be determined with as much readiness as if the pair were of the ordinary kind of spur-geer. The teeth may also be set out with the Odontagraph, if that instrument be in use in the pattern shop.

There is one property of the internal pinion which may be here pointed out, namely, the diminished friction which attends its working, as compared with an external pinion of the same diameter. To render this obvious, let P P, Fig. 2069, be the pitch circle of the wheel, Q Q the pitch circle of an internal pinion, and Q′ Q′ that of an external pinion of equal diameter. Then supposing the wheel to drive, and that it moves until the point *a* arrives at *b*; by this advance, the same point of the pinions will have arrived respectively at *d* and *c* of the circles Q Q and Q′ Q′, having both moved over a space equal to *a b*. Now it is manifest that the distance from *b* to *c* is less than the distance from *b* to *d*; but these distances may be assumed as the measure of the amount of slide of the teeth of the respective pinions in moving to their new position; for whatever may be the actual amount of slide, it must evidently be in the ratio of *b c* to *b d*, since these quantities measure the velocity of the sliding contact of the pair; and since, when the circumstances are otherwise identical, the friction is as the space passed over. It is, therefore, evident that the internal pinion has less friction than the external one; and the same figure may be employed to show that it has a larger arc of contact with the wheel, and is, therefore, other things being equal, stronger than the external pinion.

Teeth of bevel-wheels.—When a cone is made to revolve upon the surface of another fixed cone, in such a manner that their summits always coincide, the curve which is generated by a point in the circumference of the rolling cone is a kind of epicycloid, which will plainly lie on the surface of a sphere whose centre is the common apex of the cones, and whose radius is equal to the slant side of the rolling cone. From this property the curve is termed the *spherical epicycloid;* and if the cone roll on the concave surface of the base, the curve produced is denominated the *spherical hypocycloid.*

2070.



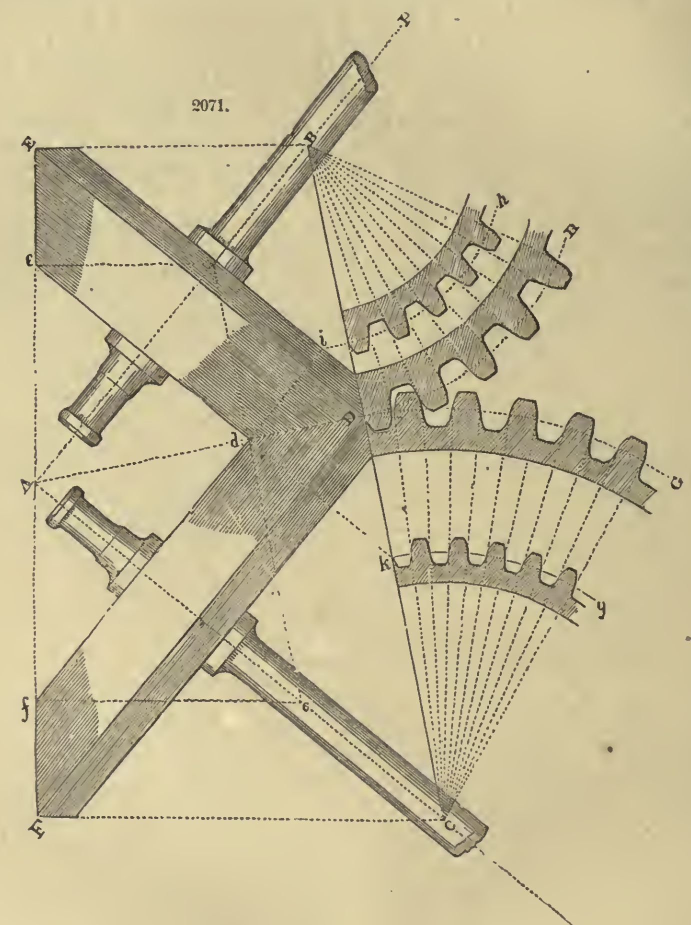
To apply this definition, let there be two cones in contact along their slant sides A *c*, Fig. 2070; and let *c* A *a* be any other cone, having its line of contact coinciding with A *c*, and having its apex at A; the axes of these three cones will then be in the same plane A R B. The circumferences will also be at the same distance A *c* from A, and will lie on the surface of a sphere whose centre is A and radius A *c*.

Now, suppose the three cones to revolve above their respective axes with the same relative velocity

as would be produced by the rolling contact of their surfaces, it is clear that the line of contact will constantly be A *c*, and calling *a* A *c*, Fig. 2070, the *describing cone*, a line *d b* upon the circumference of the surface of this directed to the common apex A, will generate one surface *f b d t* on the outside of the cone A *c m*, and another surface *d e h b* on the inside of the cone *c* A *r*. These surfaces will touch along the describing line *d b*; for since *f t d b* is generated by the rolling of the generating cone on the cone *m* A *c*, the motion of *d b* is at every instant perpendicular to the line of contact A *c*, and therefore the normal plane at *d b* to the surface generated by that line, must pass through the line of contact A *c*. In like manner the normal plane to the surface *h e d b* will pass through the line of contact of the cones, and consequently the surfaces must touch along *d b*.

Now, under these conditions, it is clear that if the rotative motion of the cone *m* A *c* be communicated by teeth to the cone *c* A *r* by their contact action, the teeth being generated by the describing cone *a* A *c*, the motion will be the same as that produced by the rolling contact of the conical surfaces, for at the beginning of the motion *f t* and *e h* coincide with the line of contact A *c*; and since the arcs *c f*, *c e*, described by the bases of the cones, are, respectively, equal to *c d*, and therefore to each other.

2071.



In practice the portion of spherical surfaces occupied by these arcs, when employed as teeth, are narrow belts of the cones extending only a small distance within the circle of the bases, and therefore cones tangent to the sphere along *c m* and *c r* may be substituted for the sphere itself without practical error. Thus draw R *c* B perpendicular to the line of contact A *c*, and intersecting the axes of the two cones at B and R; then B R revolving about A B will generate a conical surface tangent to the sphere along the base *c m*; and the same line R B revolving about A R will generate a conical surface tangent to the sphere along the base *c r* of the cone *c* A *r*. And since the arc *d f*, which really lies in the spherical surface, is very short, it may be supposed, without sensible error, to lie in the surface of the tangent cone *c* B *m*, and to be described with a circle whose diameter is equal to that of the base of the describing cone. And, in like manner, the arc *d e* may be supposed to be similarly described upon the surface of the tangent cone *c* A *r*.

These principles furnish us with a ready mode of obtaining the form of the teeth of a pair of bevel

wheels. Thus let A P and A Q be the axes of the shafts between which the motion is to be transmitted. The angular velocities with which the two shafts are driven being determined, draw A D such that it divides the angle P A Q into two parts, proportional to the numbers of teeth in the wheels respectively, or inversely proportional to the angular velocities or numbers of turns per minute of the wheels on the shafts. If we conceive the line A D to revolve about the axis A P, at the same angle P A D, the conical surface A D E will evidently be described, a portion of which, D E *e d*, is represented in Fig. 2071. Similarly, by the revolution of the line A D about the axis A Q, the conical frustum D F *f d* will be described. It is obvious, therefore, that these two cones, communicating the motion by simple contact, will transmit motion in the given ratio, and hence they are termed the *primitive cones*, and have an obvious analogy to the primitive circumferences or pitch circles of spur-wheels. In the interior of their mass the flanks and spaces are conceived to be formed, and upon their surfaces are placed the projecting faces of the teeth—the returning surfaces E *m* and F *n* of the cones, or the *crowns*, as they are termed, are defined by inverted conical surfaces formed upon the bases D E and D F; they are short frusta of the cones B D E and C D F, the common apex of which is determined by the line B D C drawn at right angles to A D. To perceive the propriety of this form of the crown, it is only necessary to consider that the ends of the teeth E *m* and F *n* will thus always be square with the surface of the primitive cones, and they will geer most completely into each other. The other ends of the teeth are defined in like manner by the conical recesses *e b d* and *d c f*, which are parallel to the exterior surfaces of the crowns; the line *b d c* being, like the exterior line, at right angles to A D.

It appears, then, that the true forms of the teeth may be described with facility upon the surfaces of the cones D E B and D F C; and for our present purpose of representing the forms of these teeth upon a plane surface, it is only necessary to conceive those surfaces spread out or developed upon a plane. Now, the development of a cone, that is, the form assumed by the superficies when laid out flat, is a sector of a circle, of which the radius is equal to the slant height of the cone, and the arc equal to the circumference of the cone at the base. In the case before us, therefore, if a circular arc D G be described from the centre C with the radius C D, it will be the development of a portion of the base, and the sector C D G will likewise be the development of a portion of the cone; and by describing an arc *k g* with the radius C *k* or C *g*, the annular space contained between *k g* and D G will be the development of the crown of the wheel. It is upon this annular segment, then, that the forms of the teeth may be drawn precisely as if it was a part of a spur-wheel; and if we suppose a piece of sheet copper or other suitable material to be cut into the form of the teeth, and wrapped upon the crown of the wheel, the outline which could thus be traced off would represent the true forms of the teeth of the bevel-wheel.

The breadth D *d* being settled by the same rules as for spur-wheels, it is obvious that the teeth must follow the taper of the cone towards the point A. Draw *d k* parallel to A C, and from the centre C describe the arc *k g*; then, as before, the segment C *k g* will be the development of a portion of the cone *d c f*, and upon this segment the forms of the upper ends of the teeth may be described. Lines drawn from the teeth on the arc D G to the centre C, will determine the magnitude of the teeth on the arc *k g*, and the teeth may thence be described, as in the figure.

The largest diameter D F is reckoned the diameter of the wheel, and, similarly, D E is said to be that of the pinion. The process which we have detailed for describing the teeth of the wheel is precisely the same as that for describing the teeth of the pinion. It is unnecessary, therefore, to particularize further, than that Fig. 2071 shows the teeth of the pinion drawn similarly to those of the wheel, upon the arcs D H and *i h*.

That the teeth thus formed will work truly together, becomes obvious, when we reflect that if any two exceedingly thin wheels, with the form of teeth described, had been taken in a plane perpendicular to A D passing through the point D and having their centres in the axes of the given wheels, they would work truly together, and their angular velocities would be in the given ratio. Now it is evident that the portion of each of the conical surfaces which is at any instant passing the line *k i* is at that instant revolving in the plane perpendicular to A D which passes through the point D, the one surface revolving in that plane about the axis A C, and the other about the axis A B. Those portions of the teeth of the wheels which lie in these two conical surfaces will, therefore, drive one another truly, at the instant when they are passing through the line *k i*, if they be cut of the form which they must have had, in order that they might drive one another truly and with the required angular velocity, had they acted entirely in the plane perpendicular to A D and about the given axes. But this is precisely the forms in which the teeth are supposed to be cut, and therefore those portions of the bevel teeth which lie in the conical surfaces will drive one another truly at the instant they are passing through the line *k i*; and, therefore, they will drive one another truly through a small arc on either side of that line, which is the condition required, since it is only through an exceedingly small distance on either side of that line that any two given teeth remain in contact. It therefore follows, that those portions of the teeth which lie in the conical surfaces D *f*, D *e*, work truly with one another throughout the whole breadth of the conical belt.

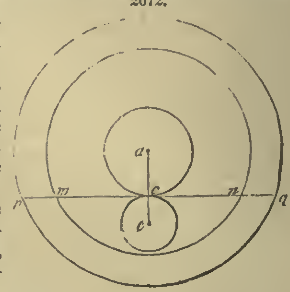
If the radius of the base of the frustum be called R, and the radius of its developed circle be r; also if the semi-angle C A D of the rolling cone $= \theta$; then $r = \frac{R}{\cos \theta}$. Hence the action of the teeth in any bevel-wheel is equal to that of a spur-wheel whose radius $= \frac{R}{\cos \theta}$; and if N be the number of teeth in the bevel-wheel, $\frac{N}{\cos \theta}$ will be the number of those in the spur-wheel of equal action. Thus if $\theta = 50°$, then $\frac{R}{\cos \theta} = \frac{1}{\cdot 64279} = 1{\cdot}556$, and therefore the action of a bevel-wheel of 50° is fully equivalent to that of a spur-wheel having a radius one-half greater, and consequently a half more teeth

This, then, is a reason for the superior action of bevel-wheels, as compared with spur-wheels of the same number of teeth; for spur-wheels always act the better the more teeth they have, and it appears that the bevel-wheel is always equivalent in its action to a spur-wheel of a greater radius, and consequently a greater number of teeth.

When a pair of bevel-wheels have equal numbers of teeth, and have their axes at right angles to each other, they are termed *mitre-wheels.* In this case $\theta = 45°$ and $\cos\theta = {\cdot}70711$; therefore taking radius equal unity, we have $\frac{1}{\cos\theta} = 1{\cdot}4$; in words, the action of a meter-wheel is nearly equivalent to that of a spur-wheel, with half as many teeth.

Skew-bevels.—When the axes are inclined to each other, and yet do not meet in direction, and it is proposed to connect them by a single pair of bevels, the teeth must be inclined to the base of the frusta to allow them to come into contact.

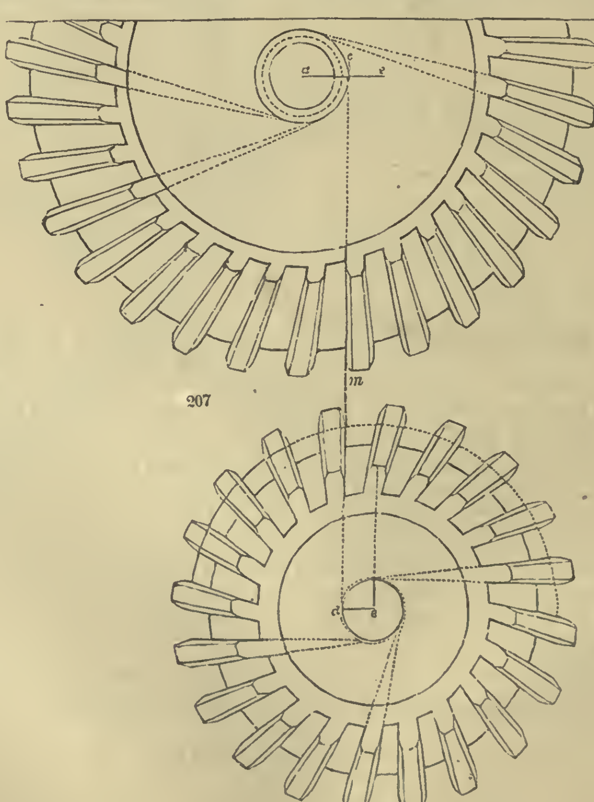
2072.



To find the line of contact upon a given frustum of the tangent-cone; let the Fig. 2072 be the plane of the frustum; a the centre. Set off $a\,e$ equal to the shortest distance between the axes, (called the *eccentricity,*) and divide it in c, so that $a\,c$ is to $e\,c$ as the mean radius of the frustum to the mean radius of that with which it is to work; draw $c\,p$ perpendicular to $a\,e$, and meeting the circumference of the conical surface at m; perform a similar operation on the base of the frustum by drawing a line parallel to $c\,m$ and at the same distance $a\,c$ from the centre, meeting the circumference in p.

The line $p\,c$ is then plainly the line of direction of the teeth. We are also at liberty to employ the equally inclined line $c\,q$ in the opposite direction, observing only that, in laying out the two wheels, the pair of directions be taken, of which the inclinations correspond.

Fig. 2073 renders this mode of laying off the outlines of the wheels at once obvious. In this figure the line $a\,e$ corresponds to the line marked by the same letters in Fig. 2072; and the division of it at c is determined in the manner directed. The line $c\,m$ being thus found in direction, it is drawn



207

indefinitely to d. Parallel to this line and from the point c draw e to e, and in this line take the centre of the second wheel. The line $c\,m\,d$ gives the direction of the teeth; and if from the centre a with radius at a circle be described, the direction of any tooth of the wheel will be a tangent to it as at c.

And similarly if a centre e be taken in the line $e\,d$, and with radius $e\,d = c\,e$ a circle be drawn, the direction of the teeth of the second wheel will be tangents to this last, as at d.

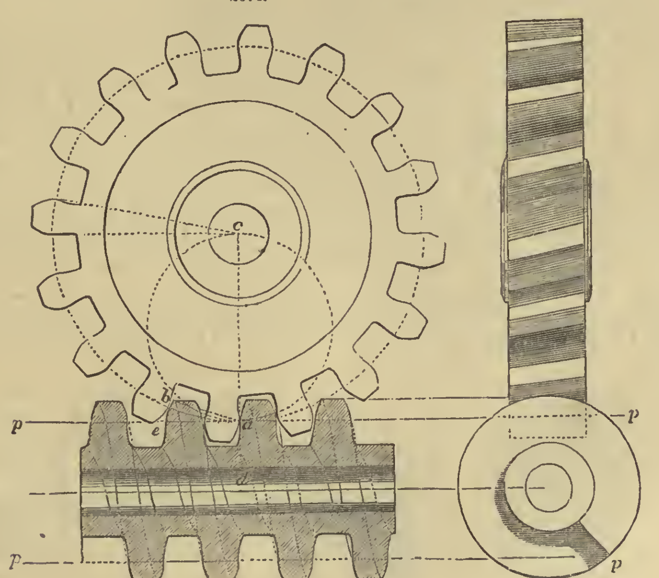
Having thus found the direction of the teeth, their outlines may be described exactly as in the case of ordinary bevel-wheels, and with equal exactness and facility.

Wheel and tangent screw.—This is often a very convenient and ready mode of reducing a high velocity.

To determine the form of the teeth of the wheel and thread of the screw, it may be remarked that, from the nature of the screw, the section of its thread, made by a plane passing through its axis, is everywhere the same; and that if a series of such sections of the entire screw be made by planes at equal angular distances round the circle, a set of figures, resembling a double rack, will be obtained alike in the number and form of their teeth, but in which the teeth will approach nearer and nearer to the extremity of the screw. Now, while revolving, the screw successively brings these sections into operation upon the whole teeth, producing exactly the same effect as if the screw were pushed endlong without rotation, in the manner of a rack. But this supposition furnishes a ready mode of obtaining the forms of the wheel-teeth and thread of the screw, upon the principle of the rack and pinion.

In Fig. 2074 $a\,c$ is the line of centres of the wheel and screw. The screw is shown in section by a plane cutting it in the line of its axis. Now, the screw being considered a driving rack, it passes a tooth of the wheel during each revolution, and therefore the point a will, at the end of a revolution of the screw, be the point b; but the thread must necessarily have continued in contact with the tooth while passing from a to b. Now, if it be required that the thread of the screw shall be in contact with the tooth at a point only, the tooth will be straight, and its obliquity equal to the pitch of the screw. But if it be desired that the thread shall be in contact with the entire side of the tooth, the outline of the wheel-teeth must be different in every section perpendicular to the axis of the wheel. The required form will be found by making such series of sections of the screw as proposed, and adapting the portion of the side of the tooth to that particular section with which it is intended to work. And since in every section two or even three teeth may be in simultaneous contact, the screw may be in contact along the entire side of those teeth.

2074.



In practice, then, the form of the tooth must be determined for the respective sections of the screw, as in the case of the rack; and the thread of the screw may obviously take the same sloped form if great strength be required.

To find the diameter of a wheel, driven by a tangent-screw, which is required to make one revolution for a given number of turns of the screw, it is obvious, in the first place, that when the screw is single-threaded, the number of teeth in the wheel must be equal to the number of turns of the screw. Consequently, the pitch being also given, the radius of the wheel will be found by multiplying the pitch by the number of turns of the screw during one turn of the wheel, and dividing the product by 6·28.

When a wheel-pattern is to be made, the first consideration is the determination of the diameter to suit the required speed; the next is the pitch which the teeth ought to have so that the wheel may be in accordance with the power which it is intended to transmit; the next, the number of the teeth in relation to the pitch and diameter; and, lastly, the proportions of the teeth, the clearance, length, and breadth.

The size and proportions of the wheel being thus settled, the operation of constructing the pattern is ready to be undertaken. Let us, in the first place, assume that the wheel is to be a radial one with six

arms; and here it must be premised, that the number of arms increases according to the diameter of the wheel—thus, with occasional deviation:

Wheels	from $1\frac{1}{2}$ to $3\frac{1}{4}$ feet diameter have	4 arms.
"	from $3\frac{1}{4}$ to 5 feet diameter have	5 "
"	from 5 to $8\frac{1}{4}$ feet diameter have	6 "
"	from $8\frac{1}{4}$ to 16 feet diameter have	8 "
"	from 16 to 24 feet diameter have	10 "

It is assumed in the numbers of this table, that the wheels are cast complete, the boss supporting the arms, and these last the rim with the teeth cast upon it. The cases of deviation are those in which the wheels are very small, and cast with a continuous *web*, instead of radial arms, and where the wheels are required to be particularly light, and to possess great accuracy: it is in this case preferable to increase the number of arms, so that they may be made thinner, and thereby incur less risk of the rim being drawn out of form during the cooling of the metal.

In arm-wheels the rim is always built of segmental pieces, cut out of plank of convenient thickness, to an external radius equal to the pitch radius of the wheel, which allows a depth equal to the flanks of the teeth for dressing. A templet or *mould* is, in the first place, made of thin, well-seasoned and dry board, and by this the form of the building segments is drawn upon the wood from which they are to be cut. Suppose that the rim is of such breadth that six thicknesses of wood are required to make it up; then four segments are cut of the requisite breadth and to the same internal radius, and two of them to an internal radius less than the former by at least as much as the intended thickness of the rim. With these segments the rim is to be built in the following manner:—

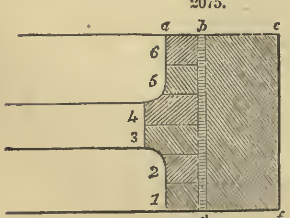
A circular plate of wood, with an iron centre on the back of it, usually with an internal screwed boss on the centre of it, having the same pitch of thread as the thread of the screw on the projecting end of the lathe-spindle, is prepared and turned up truly on the face. A circle is also described upon it to indicate the pitch line of the wheel, and to this circle the exterior arcs of the rough segments are to be adjusted.

Thus prepared, the first course of segments are planed true on one side, and fitted with sprigs upon the plate, their ends accurately jointed together, glued, and sprigged. When the glue is in some degree *set*, the plate is put upon the spindle of the lathe, and the segmental ring is turned true on the flat side; but the interior and exterior circumferences are left in their rough state. The plate is then removed from the lathe-spindle—usually a simple spindle with not more than two speeds upon it. Another course of the segments is now dressed with the plane on one side, and built upon the first. This course is bedded with glue and sprigged to the first course, observing that the joints of this course do not coincide with those of the first, but that all the former joints are covered by the whole wood of the last-laid course. The glue being allowed time to set, the plate is again put upon the lathe-spindle, and the face of the ring is dressed as before, still leaving the circumferences in their rough state.

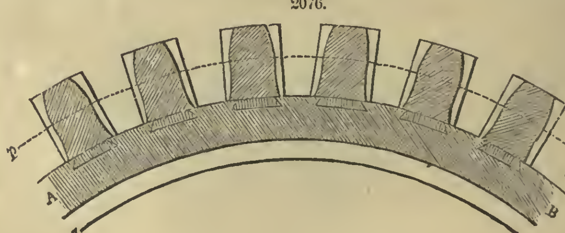
The segments of these two courses are of the same breadth, but the next course to be laid must have the increased breadth necessary to form the *web* or *feather* of the rim; this, as already stated, is usually made equal in breadth to the thickness of the rim. This course will, therefore, project inwards over the ring formed by the two courses already laid. In other respects, however, it is not different, and it is laid and fastened in exactly the same manner as the second course.

Two courses are laid of these broader segments; afterwards two others of segments of the same breadth as the two courses first laid. This done, the building of the rim is complete, and a cross section of it would present the appearance shown by the part $a\,d\,b\,c$, Fig. 2075, and an arc of it in elevation

2075.



2076.



is represented by the part A b, B a, Fig. 2076. In Fig. 2075 the courses are numbered in the order in which they are supposed to be laid, the layers 3 and 4 being those which are intended to form the web of the rim.

This process being completed, and the face-plate placed on the lathe-spindle, the exterior edge of the rim and half the interior circumference, that is, the interior of the three courses marked 4, 5, 6, are turned true to the required form. The rim is then taken off the face-plate and reversed; but is now fastened to the plate by screws passed from the back of the plate into the edge of the rim. In this position the interior of the other half of the breadth of the rim is dressed, that is, the inner circumferences of the layers 1, 2, 3, when the rim is ready to have the arms fitted into it.

In being dressed, the web or feather formed by the two middle layers, 3 and 4, is diminished in thickness, till at their edge they are together exactly of the same thickness as the arms which are to be put into the pattern; and a good practical rule is, to make these equal in thickness to *seven-eighths* of that of the rim of the wheel. In breadth they ought to be equal, at least, to the breadth of the rim, when this is calculated according to the rule of maximum strength already pointed out, and

towards the centre should be increased to $\frac{7}{6}$ths of that breadth. More commonly they are made equal in breadth to the rim, and tapered to $\frac{5}{6}$ths of that breadth at their extremities.

The breadth of the arms being determined, they are to be fitted into the rim by a *half-check* upon the web, which is done by checking out at six points, answering to the number of the arms, the breadth of an arm in the web layer marked 3. The extremities of the arms are then checked to the same depth, and fitted into their places with a little glue, and two short but strong screw-nails at each end.

The mode of fitting the arms together is different in different shops; but the easiest mode is to fit a double arm in the manner described—that is, an arm extending through the diameter, and having a half-check at the middle of its length cut to the proper angle to receive the second double arm extending, like the first, through the complete diameter. These being fitted in, two half-length arms are then inserted, butting into the wide angles left at the centre between the arms already fitted. Fillets are next inserted to fill up and round off the acute angles, both at the centre and extremities of the arms; these are intended to give additional strength to the wheel, and to facilitate the extraction of the pattern from the sand in the process of moulding. Were the acute angles left open, the sand would be ready to break down and give the wheel an uncouth and rough appearance, a result which is to be guarded against in all kinds of moulding, and more especially in wheels.

The flat arms being thus fitted in, the next operation is to insert a centre, upon which the boss or eye of the pattern may be at any time built according to the size necessary for the particular wheel to be cast off the pattern. The centre is formed of two hexagons, one laid on each side, and built of six separate pieces, or made of single solid blocks of half the depth of the rim, so that on each side the centre projects beyond the plane of the rim by half the thickness of the flat arms. The centre is firmly screwed together, and to the arms of the pattern; and on one side—the side which is intended to be uppermost in the process of moulding—a flat plate of iron, usually of the same form as the centre itself, is indented and fastened with screws to the wood. This plate has a hole in the centre, intended to admit an iron prong for starting and lifting the pattern out of the sand.

The next operation is to attach the feathers of the arms. These are placed along the middle of the flat arms, the planes of the two being at right angles to each other, so that their cross section at any point is represented by +. The breadth of the feathers diminishes from the *centre* towards their extremities, in exactly the same ratio as the flat arms; at the centre they are half the width of the rim, and consequently stand *flush* with the depth of the centre, but at the extremities which meet the rim the width is reduced a sixth. Fillets are fitted in to fill up the angles which the ends thus form with the inside of the rim, for the reasons already stated. Small *running* fillets are likewise fitted into the angles which they form with the flat arms.

The interior of the pattern may now be considered as finished; and it may be remarked that it is always desirable to have the arms completely fitted and secure, before commencing to turn the exterior of the rim; for should the rim be dressed on the outside previously to the arms being put in—which is practised by some makers—it is hardly possible to prevent its springing, and being thrown out of truth. By the process described, the arms are fitted in while the exterior of the rim is in its rough state, and consequently, although it should slightly spring, the external and most important circumference will be brought to the truth in the after process of turning. The rim is also stronger and less liable to be thrown from the truth, while in the rough state, than it is after being finished to the thickness.

After the arms are fitted into the interior of the wheel, and finished in the manner described, it is taken from the face-plate; a hard-wood plate, with a centre for the lathe-spindle, is screwed upon the eye of the pattern; it is then placed in the lathe, and the exterior of the rim is turned to the required thickness. In this process it receives a very slight bevel—usually from an eighth to a tenth of an inch in a foot—to allow it to draw cleanly from the sand in the process of moulding. About the same fraction is allowed upon the diameter of the pattern for contraction of the metal in cooling.

The next part of the operation is to cut the dovetail seats of the teeth. The form of these recesses is shown in Fig. 2076, beneath the teeth. They extend completely across the breadth of the rim, and are intended to receive the dovetail pieces (*b d*, Fig. 2075) on which the teeth are fixed. The dovetail pieces are themselves made of hard wood, and besides being otherwise convenient, they serve to bind the several layers of the rim firmly together.

These pieces are, in the first place, accurately fitted into the seats and marked, so that every piece may be replaced inserted into the proper groove to which it was fitted; the rough pieces of which the teeth are to be formed—these being cleaned with the plane on one side—are then fitted, each with a dovetail fastened by screws to its dressed side; and being cut nearly to the proper length, they are fitted into their places by the dovetails, which are made with a slight taper, so that they can be the more easily driven in its seat, and taken out again when required. The blocked teeth being thus all placed and partially fixed upon the circumference of the pattern, this is again placed on the lathe for the purpose of dressing off the ends and points of the teeth. This done, the pitch circle of the wheel is finally marked off upon the ends of the teeth with a fine point.

The pattern is now ready to have the form of the teeth drawn in, as represented in Fig. 3, by an arc of the rim, at this stage, with the outlines of the teeth also drawn. In this figure the pitch line is denoted by the dotted circle *p p*, and the form of the teeth is denoted by the shaded portions of the rectangular blocks. The various methods of obtaining the outline have already been fully explained.

To finish the pattern, it therefore only remains to dress off the teeth to the forms indicated, and to fix the dovetails permanently in their beds. This last is easily effected by a film of glue; and if the teeth are to be finished by the wheel-cutting machine, it ought to be performed previous to placing the pattern in the lathe for the purpose of dressing the ends and points of the teeth, and consequently before pitching them. But when the teeth are to be finished by hand, the order of the operation is that described and the most commonly practised.

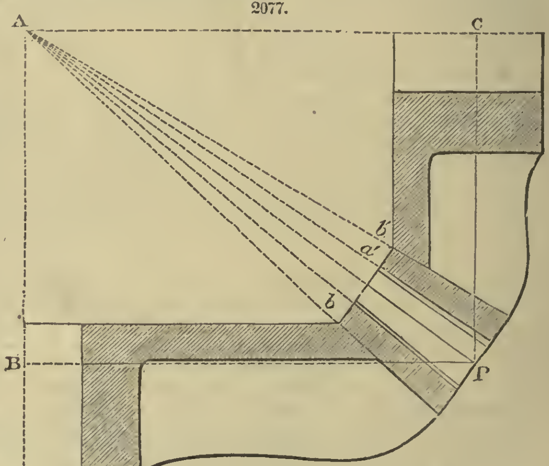
In finishing the teeth by hand, they are removed in succession, by driving out the dovetails, one only

at a time; the unshaded portions of the block are then accurately dressed off by concave and convex gage-planes adapted to the purpose; the dovetail is then fitted into its bed with a film of glue; and the tooth is complete. Every tooth is treated in exactly the same manner, until the whole number be dressed and fastened upon the circumference of the rim. But unless the operation of fixing the teeth be performed with care, there is danger of twisting the rim and throwing it out of truth.—To guard against this, the safest practice is to take always in succession the pair of teeth opposite to each other on the circumference: that is, having fitted a tooth on one side of the pattern, the tooth opposite to it on the other side ought to be the next taken, so that any tendency of the glueing to twist the rim at one point will be neutralized by an opposite tendency in fitting the next tooth.—The wheel pattern may now be considered complete.

It is to be remarked, that in making the pattern of a cast-iron wheel, it is necessary to take into account the nature of the material: the pattern must not only be of such a proportion of parts as to be sufficiently strong, calculated by the series of the parts; it must also be so proportioned that the fluid metal, when poured into the mould, shall *set* in every part as nearly as possible at the same instant. For if the parts contain disproportionate quantities of metal, it is plain that the thinner parts will cool more quickly than the others; and as cooling is attended with contraction, the parts of the casting will be put upon strain, from their contracting irregularly and faster at one point than at another; and if the irregularity be carried to a certain extent—and the limits are not wide—the casting, on being removed from the mould, will be found fractured through some of the thinner and first cooled and first contracted parts. Thus, one of the most common errors is to put too much thickness into the boss of the wheel, and in consequence it not unfrequently happens that the arms are drawn away from the rim. To avoid this, the metal round the eye ought never to be more, in arm-wheels, than twice the thickness of the rim; that is, equal to the pitch of the teeth, and this is quite sufficient in strength to resist the driving of the keys in fitting the wheel on the shaft, provided this operation be done with ordinary skill and care.

To prevent the bad effects of unequal contraction, the arms are sometimes made of a curved form. When the wheel is very light in proportion to its diameter, the arms are advantageously made with a double curve like the old letter ſ, which admits extension to a certain extent, depending on the elasticity of the material, in the direction of its length, without fracture.

2077.



The rules and directions which apply to spur-wheels, likewise apply, with slight technical modifications, to bevel-wheels. The mode of laying down the working drawings of a pair of this kind has been already explained and figured in relation to the manner of obtaining the form of the teeth; and the proportion of parts may be depicted in connection with the same drawing, by substituting for the primitive cones there given, a section of the pair as represented in Fig. 2077.

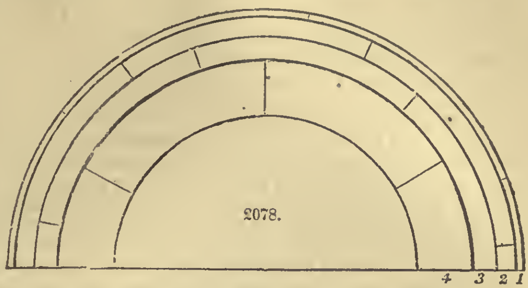
Here A P is the common pitch line of the pair, determined as before described; and B P, C P are the radii of the wheels. The breadth of the rim of the wheel is marked off from P towards A, and through that point the perpendicular $b\,b'$ is drawn. Another perpendicular to the same line is drawn through the point P, and of course parallel to $b\,b'$. Upon these perpendiculars to the pitch line A P, the lengths of the teeth are set off, and also the thickness of the rims, as indicated by the lines $a\,o$, $a'b'$. The distance $a\,a'$ will be the length of the tooth *plus* the bottom clearance; the space inclosed between a or a' and the pitch line the length of the flank of the tooth; and from the pitch line to the dotted lines at a and a' is the measure of the addendum of the teeth. The thicknesses of the rim and arms are in the same relation as for spur-wheels; but in this case they are not placed opposite the middle of the rim and boss as before, but entering on one side of the smallest diameter of the wheel, with the feather entire and projecting outwards, so that a cross section of the arm complete would present the appearance **T**, the horizontal line indicating the face-arm, or web, and the vertical piece the feather of the same. The boss or centre of the wheel is built in the manner already described, and of the same relative proportions, but altogether on the side which is furthest from the apex of the ideal cone, of which the wheel is a frustum. The feather of the arm is inserted upon the same side, and is of equal breadth to the face-arm. This is commonly sweeped by a double curve, as in the diagram, Fig. 2077, but often it is simply tapered from the rim till it meets the central boss, which, in well-proportioned wheels, is usually equal to the breadth of the rim *plus* the thickness of the face-arm.

The mode of building the rim, which, with the exception of the teeth, forms the only practical difference between wheels of this class and spur-wheels, will be understood from Figs. 2078 and 2079, which show the order of position of the segmental rings in plan and section. The segments of the ring marked 4 being cut to the proper breadth, according to the thickness of the wood used, they are sprigged to the face-plate, and dressed on their exterior surface, as before explained. But in the operation of dressing, their internal edge is commonly cut away to the diameter at which the next course

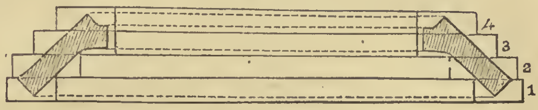
marked 2 is to be laid. This operation is not indeed essentially necessary, but it affords to the workman a better guide than a mere surface line described with the required radius, and is done without trouble.

The succeeding courses are sprigged and glued on in succession, every succeeding course being increased in diameter according to the angle which the side of the cone forms with the axis; in other words, according as the bevel of the wheel is more or less. Usually, the first two courses are *flush* on their inside circumference, as shown in the sectional diagram of Fig. 2079.

The rim being thus built, is next to be dressed on its inner circumference to the diameter required. This done, the face-arms are half-checked into the radial part of the ring marked 3, exactly as in the case of the spur-wheel pattern. The centre and feathers of the arms are inserted in succession, and before the rim is removed from the face-plate. But as soon as these operations are completed, a centre-plate is fitted to the pattern, and concentric with it; the face-plate is then removed, and the pattern is fitted on the lathe by the centre-plate, for the purpose of having the face of the rim turned. This must necessarily be true to the required bevel, and therefore implies additional care on the part of the workman whose usual method is quite exact. In the first place, he turns down the edge of the course marked 1 to the required diameter; then having fixed for the apex of the imaginary cone a point or edge, he applies a straight-edge from time to time during the process of turning, when it is evident that so soon as his straight-edge coincides with the whole breadth of the rim, and at the same time touches the apex and base of the cone, the operation of turning is complete, and not before this coincidence is attained.



2078.



2079.

An easier method is, however, to turn the greatest and least diameters in succession—with which the drawings furnish him—and afterwards to dress down the face of the rim until a short straight-edge touches the two diameters at the same time, and consequently coincides with the face of the rim throughout its whole breadth. If this be not deemed sufficiently exact, a *mould* may be formed from the drawing of two slips of wood so joined together as to coincide at the same time with the face-arm and face of the rim; the greater of the two diameters being struck, as in the method first proposed, it is evident that the mould will, on being applied, coincide with the lines on which it was found only when these agree with the drawing.

The rim being finished by one or other of the methods described, the next part of the operation is to make the dovetail-grooves which are to receive the dovetails of the teeth. These are cut with the same attention to accuracy of taper as was used to determine the bevel of the rim; for as the teeth ought manifestly to diminish in thickness as they extend towards the apex of the cone, where, if continued to that point, they would vanish, it is consistent with the general character of the work, although not essentially necessary, that the dovetails upon which they are to be fastened take the same tapered form. As in the spur-wheel patterns, those dovetails ought to pass through and take hold of each of the several courses of segments of which the rim is built, and thereby act as keys to bind them permanently together.

When the dovetails are fitted and the teeth fastened to them, they are firmly driven into their seats; and the teeth are dressed in the lathe on the ends and points to the required size. The external and internal pitch lines, that is, lines coinciding with the surface of the imaginary cone of which the wheel is a frustum, are drawn upon the ends of the teeth. Upon these lines the centres of the teeth are marked off, next their thickness, and lastly their form is described either by the method of curves, or by pattern teeth shaped according to the mode of development already explained. The dovetails are then driven out, and the body of the teeth accurately dressed to the curves traced on the ends. But this part of the operation ought to be performed in the successive manner directed for spur-wheels, and with the same attention and precaution to prevent the *twisting* of the rim, which is almost invariably the result when the teeth are fitted consecutively.

It very seldom happens that two castings are to be made from the same pattern with the same size and form of eye. It becomes therefore necessary to have a ready mode of altering the size and form of the centre according to the size and form of the eye wanted. This is provided for by making the original and solid centre smaller than any boss likely to be required for a wheel of the particular pitch. This allows of a temporary centre being built around the original one, of the particular size wanted; and as the eye is always taken out by a *core*, a *print* of corresponding diameter is sprigged on to guide the founder in the size and also in the setting of his core.

It is also necessary often to have the boss and arms more on one side of the wheel than the other, a case which cannot be provided for by making these loose. To modify the pattern for a casting of this kind, the difference is made up temporarily, on the side to which the increase is desired, by pieces simply sprigged to the proper arms and centre of the pattern; the quantity to be removed from the other side is then carefully marked off by chalk lines drawn upon the feathers of the arms and round the centre; and when the pattern is moulded, the parts so chalked off are filled up in the sand. If

the modification, however, be of such extent as to alter the position of the face-arms, it then becomes necessary entirely to inclose the arms with thin board, forming a species of box, of a depth determined on the one side by the position of the arms and centre of the pattern, and on the other by the position which they are to occupy in the casting. The pattern being moulded in this condition, there is left only large open spaces for the arms and centre; and into these the new arms and centre are built by cores formed by core-boxes made to the particular shape and size desired. This is perhaps one of the greatest niceties of green sand moulding.

For wheels of small diameter and pitch, it is now becoming a general practice to use metal patterns, of cast-iron and brass In works where small machinery is made, and which are commonly provided with wheel-cutting machines, the rim is usually made of sufficient thickness to allow the teeth to be cut upon it, and yet to leave the proper thickness of metal for strength between the bottoms of the spaces, and the *web-plate* which connects the rim with the eye-boss of the wheel. Sometimes also the same method is adopted with wheels which are *crossed-out*. This method admits of greater accuracy than that described for large wheels; for before proceeding to cut the teeth of the wheel, the casting may be accurately adjusted to a centre in the lathe, and have the strength of its parts at the same time exactly proportioned to the pitch of the teeth. The centre wheel thus admits of being polished, a process which not only improves the appearance, but likewise insures correctness of the work.

The mode of constructing the pattern of a mortise-wheel, differs from the ordinary routine for toothed patterns in little more than the omission of the teeth. The rim is however made wider than that of a toothed wheel of the same pitch, by twice the thickness of tooth; and its thickness is double that of the ordinary toothed rim.

The manner of construction is this: The rim is built and dressed, and has the arms and centre fitted into it as already described. The dovetails are also fitted into the corresponding grooves in the rim; but these, instead of having teeth fixed upon them, carry simply their pieces to serve as core-prints to guide the founder in laying in his cores to make the mortises for receiving the tails or tenons of the teeth. These prints are made in length equal to the breadth of the teeth, and in breadth equal to their thickness. When the pattern is moulded the prints leave their impressions in the sand, and these are filled by cores of corresponding size and of a depth equal to the thickness of the rim.

The rim of the casting being carefully *faced up*, or dressed in the lathe, is ready to be cogged. The cog-tenons are in the first place fitted tightly into the mortises of the rim; the wheel is then put into the lathe and the points of the teeth and ends of the tenons are dressed off in precisely the same way as the wooden teeth of a wheel-pattern: the pitch lines of the wheel are then run upon them with a point, and the curves of the teeth being described, the cogs are ready to be taken out and finished by hand; or the wheel may be put into the wheel-cutting machine, and cut to the form and pitch required.

Wooden cogs, it will be seen from the rules already given for the strength of the teeth of wheels, ought to be thicker than iron teeth in the proportion of the cube of 14 to the cube of 12; the difference is commonly made greater, and perhaps correctly, as the strain falls principally upon the necks of the tenons of the teeth. This allows of the iron teeth of the wheel with which the cogs are to geer, to be dressed to the exact form and thickness, and polished on their acting surfaces, to prevent injurious abrasion of the wooden cogs. By dressing, the iron teeth are however diminished in strength, and consequently a pair of wheels of the kind here described ought to be made fully more strong than wheels of the ordinary kind.

When wheels are beyond a certain size, it becomes necessary to cast them in segments, which are afterwards united to form the complete wheel. The pattern of the rim of a wheel of this kind consists of a single segment of which the required number of castings are made. The segment is provided at the ends with the requisite means of connecting the parts together, and to the arms which are also commonly cast separately, and bolted to the rim and centre. As the rim in this case may be cast of any degree of thickness without risk of injury to the wheel, it is commonly made with recesses to receive the ends of the arms, which are fixed in their places by keys, bolts, or both, according to the mode of construction preferred by the maker. The segments are also sometimes, and advantageously, dovetailed into each other on the inside at the ends, and the arms are fitted also by dovetail-checks and bolts to the middle of their length. This mode of fitting requires great accuracy of workmanship, but when well executed it possesses a degree of neatness which cannot be otherwise attained. The arms are fitted in the same manner to the centre.

Another mode is to cast each segment with an arm attached to the middle of its length, and to fit these upon the centre in the way described. Thus if the wheel have eight arms, the rim will be composed of eight segments, and the centre will be cast with an equal number of recesses to receive the ends of the arms.

When the wheels again are of an intermediate size, too large to be cast in one piece, yet not larger than will admit of their being cast in two parts, they are then cast in halves, each half complete in itself from the circumference to the centre. These halves are then fitted together to form the complete wheel. The manner of fitting is various. The common way is to cast each half with strong flanges throughout the whole diameter, and to bolt these together. Wheels constructed in this way, must of necessity have an *even* number of arms, so that the division may be effected through the middle of an arm running through the diameter of the wheel. The two flanges, that is, the flange of each segment, will form the feather of that arm, but double the thickness of the ordinary feather.

We have seen wheels put together in three pieces in this way very satisfactorily, but the difficulty of fitting is then very considerably increased. It is also not uncommon to cast the segments with strong flanges only at the rim and centre, and to trust to these alone to hold the segments of the wheel together. This greatly reduces the work of fitting, and we do not see that sufficient strength could not thus be attained.

With respect to the material of the patterns of wheels, it is only necessary to observe that the common practice of using white pine for the arms and rim, and hard wood for the teeth, and their dovetails

is both economical in point of time and expense. But in all cases where the teeth are expected to require no dressing after leaving the sand, it is of importance that those of the pattern be formed with the utmost accuracy, and have a smooth surface. And it may be here observed, that unless in the circumstances referred to, it is not desirable, in point of economy of wear, to dress the teeth, at least to the extent of removing the cast surface, which is by far the hardiest and most durable part, and after working some time, it takes likewise a smoother surface than can be given to the softer metal beneath. The surfaces ought, however, to be cleaned of any imbedded sand, and excrescences which may be found adhering to them when taken out of the sand; and it is also of advantage to *run-up*, or clean the points of the teeth in the lathe when the wheel is small.

The key-seats of the eye are usually cut by the slotting machine, and of a breadth proportioned to the size of the eye, and not to the pitch or diameter of the wheel.

Shafting is a department of mill-work which embraces some of the most important considerations within the compass of practical dynamics. If on the one hand shafting be too light, it will be of little importance that the wheels are accurately made, and proportioned to the power conveyed; the tremor and hobbling gait to which an overburdened condition of the shaft-geer invariably gives rise, will speedily destroy their adjustment by irregular wearing of the teeth. The bush-brasses at the same time suffer, and the evil is aggravated till ultimately a sudden failure at some important point sets the whole at rest. On the other hand, if the shafting be made too heavy, an unnecessary expense is incurred in the construction; and, what is usually of more importance, and in most cases of more serious consequence, a waste of power is occasioned by the unnecessary friction and wear produced by the superfluous weight at the journals and footsteps. Both extremes are thus to be avoided with equal care.

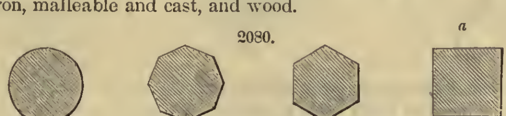
One important feature of our modern practice is the higher velocities at which the main shafts are impelled. By this means the geering can be made lighter for the same power, and therefore more durable, since the friction and inertia are diminished, and the impulsion thereby rendered more steady and uniform. The power of the prime mover is therefore economized; and if that power be derived from steam, a corresponding saving is effected in the maintenance of the engine; and if water power be employed, a proportionally greater quantity of machinery can be impelled by the same waterfall. Hence the principles which ought to guide the engineer in the construction of a system of shaft and wheel geering is, to regulate the connections in such a manner that the inertia of the mass and the friction of the motion may be reduced to a minimum, and to effect this purpose the velocities and strength of the parts must be adjusted to one another, and to the speeds of the machines in which the power is to be expended.

But before entering upon the investigation of the practical bearings of this general principle, it may be necessary to glance briefly at the various kinds of shafting employed by the millwright and engineer. As respects material, there is only the choice between wood and iron; and the forms are chiefly cylindrical and square, but sometimes octagonal. When large wooden shafts are employed, as they sometimes still are, especially as axles of wooden water-wheels, they are commonly made of one solid log, with gudgeons inserted into their ends, according to a method to be subsequently described. But the scarcity of large timber has not unfrequently led to the substitution of shafts built of planks, and these, when properly made and of sufficient strength, have been found little less durable, and much less expensive.

Iron shafts are of two varieties—forged and cast. Those of large size are commonly of cast-iron, while smaller shafts and *spindles* are formed of malleable iron. The form most common to both is that of a cylindrical solid; but often they are square, sometimes octagonal, and occasionally hexagonal. Cast-iron shafts are also not unfrequently made with ribs upon their peripheries, and then they are called *feathered shafts*—probably from the slight resemblance which they bear to the feathered part of an arrow. Cylindrical shafts of large size are also sometimes cast tubular, and they are then termed *hollow* shafts.

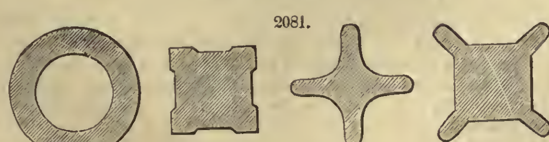
The subjoined figures represent the forms of cross section most commonly adopted in shafts of the respective materials, iron, malleable and cast, and wood.

2080.



Malleable iron, cast-iron, wood.

2081.



Cast-iron.

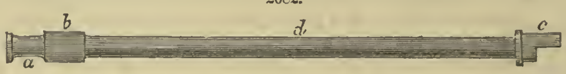
In respect of these forms, the cylindrical is in general to be preferred, not that it possesses greater strength, as is commonly supposed, for the same weight of materials, but because it is the simplest and the most elegant in appearance when mounted. Feathered shafts, as they are commonly made, although their strength to withstand lateral pressure be augmented by the breadth of the feathers, are very rarely free of tremor from want of substance between the feathers, and unequal distribution of the material around their axes. It is, however, an error to assume, with Tredgold and others, that the circle is the only form of section which gives to the axes the property of offering in every direction the same resistance to flexure; for it might readily be proved geometrically that the square section must offer the

same resistance to flexure in the direction of its sides and diagonals; and what is true of the square, is equally true of a great number of other figures which may be formed by combining symmetrically the circle and square. The hollow cylindrical form admits of being adopted only in shafts of the very largest class, and for the same weight of material is greatly the strongest form that can be employed, and the best adapted to resist the combined action of torsion and cross strain. It is difficult to make a casting of a tubular form below a certain diameter with the necessary accuracy; and, therefore, in shafts of small diameter it is much greater economy to make them solid.

The sections represented above, Figs. 2080 and 2081, must be understood to be those of the body-parts of the shafts; but the shaft is very seldom uniform throughout its length even when cylindrical, and never when of any other form; for whatever be the figure of the body-part, the journals must always have a circular section, and every shaft must—as will be subsequently seen—have at least one journal or gudgeon on which it revolves. If the shaft be one of a line leading the power to some distant point from the source of motion, it will likewise have its extremities adapted to *couple* with the shafts between which it is placed; and if intended to carry a wheel or belt-pulley, it is commonly provided with a *boss* on which the same is keyed. In very large shafts the boss may be replaced by four snugs projecting from the periphery to receive the keys, and when the shaft is of cast-iron and square, as shown by the section marked *a*, the part to receive the wheel takes frequently the form of section marked *b*.

The following cut, Fig. 2082, illustrates the usual form of a cylindrical iron shaft, on which a wheel is to be keyed at the enlarged part *b*, denominated the *wheel-boss*, and which is to be coupled to another shaft at the part *c*, by what is termed a *half-lap* coupling, to be afterwards described. The journal is marked *a*, and has the same diameter as the body-part of the shaft marked *d*.

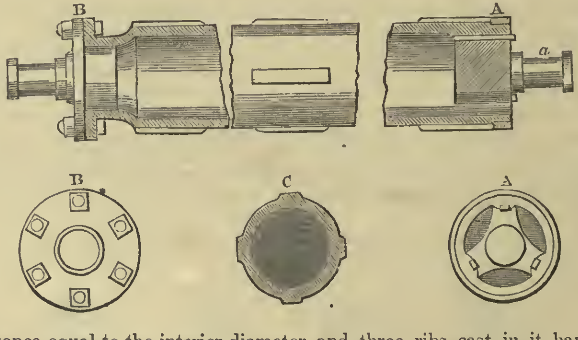
2082.



In ordinary shafting, the gudgeons are *now* always formed of the same piece as the shaft, and turned. But in ordinary water-wheels the axles are formed of cast-iron, usually hollow, with independent gudgeons fitted into their extremities; and when made of wood, the gudgeons must of necessity be inserted.

The drawings in Fig. 2083 show the general form of a hollow cast-iron axle for a water-wheel, with two modes of fitting the gudgeons. The form of gudgeon fitted into the end marked A is peculiarly adapted to axles of this kind, on account of its simplicity. The metal of the shaft is here thickened

2083.



internally to a distance equal to the interior diameter, and three ribs cast in it have key-seats cut in their faces. The gudgeon marked *a* has three arms cast or forged upon it, (according as it is made of cast or wrought iron,) of the same length as the ribs on the interior of the shaft; and these being dressed in the lathe at the same time that the gudgeon is turned, are correspondingly key-seated. A wrought-iron hoop being driven red-hot upon the end of the shaft to prevent it from splitting, the arms of the gudgeon are adjusted in their places and keyed tight, the keys having as little taper as can conveniently be allowed for fitting. They are thus less likely to become loose in their seats.

Sometimes the gudgeon is provided with four arms, but it is commonly admitted that the mode described is preferable, because with three arms the keys must all bear equally, whereas when four are employed it is difficult to obtain a uniform tightness of the set.

The form of gudgeon shown at B is more applicable to a vertical than to a horizontal shaft, although employed indifferently with both. The shaft is in this case cast with a projecting flange round its extremity, of the same diameter as a similar flange cast upon the gudgeon. The interior of the end of the shaft is, in the first place, bored out truly cylindrical, and the flange is at the same time faced. The flange of the gudgeon is likewise faced, and a piece cast on the back of it is turned to fit into the turned part of the end of the shaft; the two flanges are then brought together and secured in tight metallic contact by bolts and nuts.

In this form of gudgeon the pivot is sometimes formed of wrought-iron or steel, and fitted into the flange and socket, which must of necessity be cast. This allows of the pivot part being replaced when worn out, at less expense than if the whole consisted of one piece.

To render this a good and lasting arrangement, it would be necessary to make the socket of the

gudgeon of considerable length, and to bind the two flanges together by a hoop of malleable iron, embracing both their circumferences, and put on red-hot.

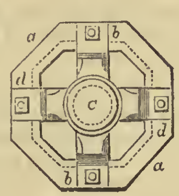
When the shafts are of small diameter these contrivances are not usually employed; the part of the gudgeon which enters the shaft is formed as a solid cylinder, in the surface of which the key-seats are formed; the cylinder fits loosely into the end of the shaft, and is made tight by the keys, as in the first method described. The shaft, with its gudgeons fitted, is then put into the lathe, and the pivots are turned truly concentric with the body-part, and of the strength desired, the original diameters being usually much greater to allow for any inaccuracy in the fitting. This is also sometimes practised with shafts of the larger class; but more commonly the gudgeon part alone is dressed in the lathe, and the adjustment intrusted to the fitter, who can adapt his keys to obviate any small inequalities due to the casting.

The form of gudgeon most approved of for wooden water-wheel axles is that known as the *cross-tail gudgeon*, which consists of a pivot piece projecting from the centre of a cross, roughly represented by $\vdash$ in side elevation, and by $+$ on end. The vertical pieces forming the tails are let into mortises cut in the end of the shaft, and the pivot coinciding with the axis of the shaft, the mortises are filled up on each side of the neck by pieces of wood. A strong malleable-iron hoop is then wedged tightly on the end of the shaft, in order to fasten and retain the pivot of the gudgeon in its parallel position.

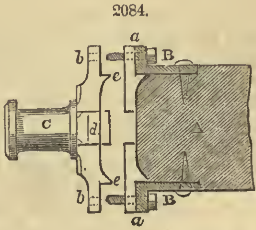
This gudgeon has also been made with only two cross-tails; and in well-finished work the tails, whether two or four, pass within a malleable-iron ring, which embraces the shaft at the point where they project to the circumference of the shaft: this ring being made slightly less in diameter when cold, is fitted in its place at a temperature of red heat, and contracting, embraces the tails and shaft tightly. The second ring at the end is made of full size, and fixed by wedges. As an additional security, the arms of the cross are sometimes fixed by screws, which pass through into the wood of the shaft. The arms are in this case made thicker, and do not enter so far into the shaft. The screws by which they are fastened are made of considerable length, and the distance being noted to which they will pass into the timber, mortises are cut at these points large enough to receive nuts suitable to the bolts. The nuts being dropped into their places, opposite to the screwed ends of the bolts, they are screwed up by a spanner, and thereby hold the arms tightly in their place.

By these and similar means the gudgeon can be made for a time quite fast; but when it is considered that the direction of the stress which tends to loosen it is continually changing, and that such stress being exerted on wood, a material which is comparatively very easy and permanently compressed, it is not difficult to perceive that the fastening of gudgeons must have been a matter of much importance to the older millwrights, and that with all their care and ingenuity they seldom succeeded in rendering them firm and lasting. Accordingly several modifications of the schemes described have from time to time been resorted to with indifferent success. The best of these is undoubtedly that of Robert Hughes, described in the Transactions of the Society of Arts, (vol. xxxi. p. 223.) "It consists in casting the gudgeon with cross-arms, which fit into notches in an octangular box of cast-iron which has been previously fixed on the end of the shaft." The contrivance is represented by Figs. 2084 and 2085, in which "A represents (in section) a portion of the end of a wooden shaft of an octangular form; it is long enough to reach across the pit in which the water-wheel works, and, having a gudgeon at each end, is supported and revolves upon them in proper bearings. B B is the cast-iron box accurately fitted on the end of the shaft, and being wedged tight, prevents the wood from splitting as effectually as any hoops can do. Upon the end of the box is a projecting flange *a a*, with four notches to receive the cross-arms *b b*, *d d* of the gudgeon C. This cross is firmly attached to the box by four screw-bolts, which pass

2085.



2084.



through the flange and the ends of the cross-arms. The figure in section (in which the cross and box are represented separately to show more clearly the mode of putting them together) explains a further precaution which is necessary for strength; and which consists in the inside face of the cross having projections *e e*, which enter the end of the box, and keep the pivot truly in the centre, and prevent any lateral strain on the bolts, which have thus merely to hold the gudgeon fast to the end of the box. When a gudgeon, fitted according to this method, becomes worn out so as to require replacement, it can be removed by taking off the four nuts, and a new one applied; the gudgeon also being of small dimensions, the cylindrical part admits of being conveniently turned in a lathe, which is a considerable advantage."

This gudgeon involves nevertheless a considerable deal of workmanship, and the real practical advantage which it possesses over the common cross-tail gudgeon is simply, that it does not require the end of the shaft to be impaired by mortising, and affords the means of renewing the gudgeon when the pivot becomes worn out, with more facility and without injury to the shaft.

The stress to which water-wheel gudgeons are subject is generally of a lateral and simple character. The gudgeons have manifestly all the weight of the shaft, wheel, and sometimes the water, to sustain, and ought, therefore, to be made sufficiently strong for that purpose; but they ought obviously to be as little as possible increased in diameter beyond the required strength, and a proper allowance for wear to insure durability.

In practice it is common to make the length of the gudgeon equal to the diameter. Establishing this as a principle, from experiments on the strength of iron, we deduce the following practical rules:—

Find the weight in pounds to be supported by each gudgeon, extract the square root of the

number, and that root divided by 25 when the gudgeon is cast-iron, and by 26 when it is wrought-iron, will give the diameter and length of the gudgeon from the shoulder to the extremity expressed in inches.

Example.—The gross weight on the gudgeons of a water-wheel is 86,800 lbs.; required their diameter, the gudgeons being cast-iron? The gross weight being 86,800 lbs., that upon each gudgeon will be 43,400 lbs., and $\sqrt{43400} = 208{\cdot}32667$, which divided by 25 gives 8·3336 inches for the diameter of the gudgeon. The actual diameter of the gudgeons is in this case 8·5 inches, and they have worked in cast-iron bearings for upwards of twelve years, the bushes being only once and lately renewed during that period.

With respect to the strength of shafts generally, there are different circumstances to be considered in the calculation. It frequently happens, in examining the conditions under which the shaft is to be placed, even when the stress is manifestly compounded of lateral pressure and torsion, that one of these may be neglected in the calculation of the strength. Thus the effect of lateral pressure is to produce deflection, which must be provided against, and ought not to exceed $\frac{1}{100}$th of an inch in one foot of length; if, therefore, the dimension requisite to give this degree of transverse stiffness be greater than is required for the twisting power brought on at the circumference, this latter strain may obviously be disregarded; and conversely, when the torsion is great and the lateral pressure insignificant, as in the case of vertical shafts, the effect of the former only requires to be considered. And again, when the shafts are long, and have the power and resistance acting at their extremities, it is not enough that the body part of the shaft be sufficiently stiff to prevent deflection beyond the proper limit; it must have sufficient dimensions to prevent twisting beyond a certain quantity; and in estimating the effect of torsion, it is not so much the shaft itself which ought to be considered as the journal, which is constantly exposed to wear, and which is thereby rendered more liable to rupture.

In examining successively the amount and effect of these species of stress, and the circumstances under which their intensity is developed separately and in combination, the first part of the inquiry which naturally claims attention is the degree of strength requisite to withstand lateral stress. In this inquiry it is not the ultimate transverse strength, but the stiffness of the shaft which claims attention; in other words, the resistance which the material offers to bending by its own and any superadded pressure tending to deflect it from the straight line. Now, the shaft being square, if

d = the depth or side of the square in inches,
L = the length of the shaft in feet,
W = the weight or pressure upon it in lbs.,
δ = the deflection at the middle of the shaft in inches,
M = the modules of elasticity; then

1°. When the shaft is supported at both ends, and the stress is intermediate,

$$d^4 = \frac{432\,L^2\,W}{M\,\delta} \quad \text{or} \quad d = \sqrt[4]{\left\{\frac{432\,L^3\,W}{M\,\delta}\right\}}$$

That is, in words—Multiply the weight upon the shaft in lbs. by the cube of the length expressed in feet, and by 432, and divide the product by the value of M, multiplied by the assumed amount of deflection δ to be allowed: the fourth root will express in inches the depth of the side of the shaft when the transverse section is square. Or the square root will express the area in square inches of the cross section when the shaft has any other form.

This rule answers for any material of which the weight of the modulus of elasticity M is known. In its general form it is, however, laborious, from the magnitude of the numerical quantities involved: fixing upon particular values of M for the different materials to be employed, and also fixing the maximum value of δ, it may be greatly simplified. In shafting, as already remarked, the deflection should not exceed $\frac{1}{100}$th of an inch for every foot of length; hence,

I. *For wood.*—Taking M generally = 1,500,000 lbs. and $\delta = \frac{L}{100}$ inches.

Then for square shafts, d being the depth of the side of the square in inches,

$$d^4 = \frac{L^2\,W}{35} \quad \text{(A)}$$

And for round shafts, d being the diameter in inches,

$$d^4 = \frac{L^2\,W}{20} \quad \text{(B)}$$

II. *For cast-iron.*—Taking M = 18,000,000 lbs. and $\delta = \frac{L}{100}$ inches.

When the section is square, d being the depth of side,

$$d^4 = \frac{L^2\,W}{412} \quad \text{(C)}$$

When the section is round, d being the diameter,

$$d^4 = \frac{L^2\,W}{240} \quad \text{(D)}$$

III *For wrought-iron.*—Taking M = 24,500,000 lbs. and $\delta = \frac{L}{100}$ inches as before.

When the section is square and d the side,

$$d^4 = \frac{L^2 W}{567} \quad \text{.....................(E)}$$

When the section is round and d the diameter,

$$d^4 = \frac{L^2 W}{334} \quad \text{.....................(F)}$$

2°.—If the stress be uniformly distributed over the length of a square shaft it will produce the same eflection of the shaft in the middle as $\frac{5}{8}$ths of that weight applied at that point. And if W be the weight of the shaft itself, and it be otherwise unloaded, the deflection produced by its own weight will be,

I.—For cast-iron shafts when square,

$$\delta = \frac{L^4}{256000\, d^2} \quad \text{.....................(G)}$$

And when the shaft is cylindrical and solid,

$$\delta = \frac{L^4}{150000\, d^2} \quad \text{.....................(H)}$$

II.—In wrought-iron shafts when square,

$$\delta = \frac{L^4}{336000\, d^2} \quad \text{.....................(I)}$$

And when the shaft is cylindrical and solid,

$$\delta = \frac{L^4}{198000\, d^2} \quad \text{.....................(J)}$$

As an example of the application of these rules, let it be required to determine the deflection at the middle of the length of a 3 inch wrought-iron round shaft of 15 feet length betwixt its bearings:

$$\text{Here } L = 15, \text{ and therefore } L^4 = 50625,$$
$$d = 3, \text{ and therefore } d^2 = 9;$$
$$\text{Hence, } \delta = \frac{L^4}{198000\, d^2} = \frac{50625}{1782000} = \cdot 03157 \text{ inch.}$$

The converse of this case frequently occurs; that is, having determined the diameter of the shaft, and assumed a maximum amount of deflection to be allowed, what may be the distance between the bearings?

Let the maximum deflection be $\frac{1}{100}$th of an inch for every foot of length, that is, $\delta = \frac{L}{100}$ inches on the whole length; then from equation,

$$\text{(G)} \quad L = \sqrt[3]{2560\, d^2} \quad \text{(K)}$$
$$\text{(H)} \quad L = \sqrt[3]{1500\, d^2} \quad \text{(L)}$$
$$\text{(I)} \quad L = \sqrt[3]{3360\, d^2} \quad \text{(M)}$$
$$\text{(J)} \quad L = \sqrt[3]{1980\, d^2} \quad \text{(N)}$$

Thus, let the diameter $d = 3$ inches, as in the last example, the shaft being of wrought-iron and a solid cylinder; then from equation (N) we have

$$L = \sqrt[3]{1980 \times 9} = 26 \cdot 12 \text{ feet,}$$

the distance between the bearings, on the condition that the deflection of the shaft by its own weight shall not exceed $\frac{1}{100}$th of an inch for each foot of the length. This being 26 feet in all, the deflection at the middle will be $\cdot 26 = \frac{1}{4}$ inch nearly, which is a safe allowance, in ordinary cases, on this length of shaft.

Again, if the torsion be very small, and it be more convenient, and possibly more economical, to adjust the diameter of the shaft to the limit of deflection than the length of the shaft, this being fixed, then, assuming the value of δ as before, we obtain from equation

$$\text{(K)} \quad d = \sqrt{\left\{\frac{L^3}{2560}\right\}} \quad \text{(O)}$$
$$\text{(L)} \quad d = \sqrt{\left\{\frac{L^3}{1500}\right\}} \quad \text{(P)}$$
$$\text{(M)} \quad d = \sqrt{\left\{\frac{L^3}{3360}\right\}} \quad \text{(Q)}$$
$$\text{(N)} \quad d = \sqrt{\left\{\frac{L^3}{1980}\right\}} \quad \text{(R)}$$

Thus, the length between the bearings being 30 feet, what ought to be the size of a cast-iron square

shaft in which the deflection shall not exceed $30 \times \cdot01 = \cdot3$ inch at the middle of the length? In this case the rule is equation, (O,) whence,

$$d = \sqrt{\left\{ \frac{30^3}{2560} \right\}} = \sqrt{10\cdot59} = 3\cdot2542 \text{ inches,}$$

the side of the square, the area of the cross section of the shaft being 10·59 square inches.

The distances between the bearings given in these examples are not, however, such as would be adopted in practice; but simply show the limits in reference to the deflection of the shaft by its own weight. The spring to which a shaft is always liable in working, from irregularities in the power and resistance, even when its deflection is far within the limit prescribed, renders bearers in general not more than 10 feet apart necessary to prevent vibration; these are usually of a less substantial character than those in the immediate vicinity of the working points.

III. It is sometimes found unavoidably necessary in a system of geering to *overhang* a wheel or belt pulley, leaving only one end of the shaft supported, while the stress falls upon the other. The equation for the stiffness within the elastic limit is in this case,

$$d^4 = \frac{4\ l^3\ W}{M\ \delta} = \frac{6912\ L^3\ W}{M\ \delta}$$

When L = the length of the shaft from the point of pressure to the bearing expressed in feet, and M the weight of the modulus in lbs., d and δ have the same values as before.

Now, in cast-iron, the value of M was before assumed = 18,000,000 lbs.; therefore, when the shaft is cylindrical, (the only case which it is necessary to consider) we shall have

$$d^4 = \frac{L^3\ W}{1532\ \delta} = \frac{L^2\ W}{15} \quad \text{.............................. (S)}$$

When $\delta = \frac{L}{100}$ inches. This equation determines the least diameter of the journal, which is never greater than that of the shaft.

Again, the value of M for wrought-iron is 24,500,000 lbs.: hence, for round shafts of that material,

$$d^4 = \frac{L^3\ W}{2085\ \delta} = \frac{L^2\ W}{21} \quad \text{.............................. (T)}$$

When $\delta = \frac{L}{100}$ inches as before.

As an example of this case, let it be required to determine the diameter of the journal of a malleable iron shaft on which a belt pulley is overhung, at a distance of $2\frac{1}{2}$ feet from the journal? Let the weight of the pulley be 180 lbs. and the tension of the belt, when driving, 320 lbs.

Here L = 2·5 feet, and W = (180 + 320) lbs. = 500 lbs.

$$\text{Hence, } d^4 = \frac{(2\cdot5)^2 \times 500}{21} = 148\cdot81,$$

$$\text{And } d = \sqrt{\sqrt{148\cdot81}} = \sqrt{12\cdot21} = 3\cdot49 \text{ inches, the diameter required.}$$

In this equation it is presumed that no flexure of the shaft takes place beyond the journal, and, to fulfil that condition—which is necessary to save the bearing, and avoid undue friction—the shaft must either be made very strong or have only a short distance between the first and second bearings. Thus, suppose a pulley overhung on the shaft, to prevent the shaft from springing between the proper bearings, an intermediate bearing is placed at a short distance behind the bearing nearest the pulley, which prevents upward flexure, and thereby saves the pillows adjoining the stress. It may also be here observed that the distance between the bearings which our rules seem to allow are greater than is commonly practised in modern mill-work; steadiness of motion is much desired, and, as friction is not increased by the number of bearings, provided these be properly made and fixed, it is reckoned good economy rather to multiply the bearings than to risk even the small amount of deflection which we have taken as a safe limit.

We have hitherto referred only to two forms of shafts—square and round; and these solid. But the same rules may be considered to apply generally to any other forms of solid section; for knowing the side of a square shaft of a given strength, the cross sectional area of any shaft of equivalent strength is thereby approximately determined, however different in form.

Mr. Tredgold's rule for the strength of hollow shafts within the elastic limit, the cylinder being supported at the ends, is

$$\sqrt[3]{\left\{ \frac{W\ L}{500\ (1 - N^4)} \right\}} = d,$$

and is thus expressed verbally: Fix on some proportion between the diameters; let the external diameter be to the internal as 1 is to N; the number N will always be a decimal, "and ought not to exceed 0·8." Then multiply the length L in feet by the weight W to be supported in lbs. Also, multiply 500 by the difference between 1 and the fourth power of N, and divide the product of the length and the weight by the last product, and the cube root of the quotient will be the exterior diameter d of the shaft in inches. The interior diameter will be the number N multiplied by the exterior diameter, and half the difference of the diameters will be the thickness of metal.

As an example of the application of this rule, let it be required to find the dimensions of a hollow shaft for a water-wheel, which, including the weight of the water in the buckets, weighs 44,800 lbs. the whole length of the shaft is 8 feet, from which, deducting 5 feet, the width of the wheel, leaves 3 feet for the length of the bearing: required the exterior and interior diameters of the shaft?

Making $N = \cdot 7$, its fourth power is $\cdot 2401$; and $1 - \cdot 24 = \cdot 76$. Therefore, we have by the rule $\frac{44{,}800 \times 3}{500 \times \cdot 76} = 354$ in the nearest whole number; and the cube root of 354 is 7, the exterior diameter in inches; and 7 inches $\times \cdot 7 = 4 \cdot 9$ inches, the interior diameter.

When the shaft is supported at the ends, and the stress is not in the middle of the length, but at distances p and q from the respective ends, the rule becomes,

$$d = \sqrt[3]{\left\{ \frac{4\ W \times p\ q}{500\ L \times (1 - N^4)} \right\}}$$

Thus, let the weight of a wheel and other pressure on the shaft be 36,000 lbs. $= W$; the distance of the point of stress from the bearing at one end being 3 feet $= p$, and the distance from the other bearing 1·5 foot $= q$; and let $N = \cdot 8$; required the exterior and interior diameters of the shaft?

The fourth power of ·8 is ·409; and $1 - N^4 = \cdot 591$. Therefore, by the rule

$$d^3 = \frac{4 \times 36{,}000 \times 3 \times 1 \cdot 5}{500 \times 4 \cdot 5 \times \cdot 591} = 485;$$

and the cube root of 485 is $7 \cdot 86 = d$, the exterior diameter in inches; and 7·86 inches $\times \cdot 8 = 6 \cdot 3$ inches, the interior diameter. These rules give the strength of hollow shafts within the elastic limit, but when the deflection is restricted to a given amount, the diameter must be determined from the rule

$$\frac{d = \text{diameter of solid shaft}}{\sqrt[4]{1 - n^4}} = D;$$

the diameter of a hollow shaft of the same stiffness as the shaft of diameter d.

The second species of stress to which shafts are liable is *torsion*. The question of torsion divides itself into two cases as applied to shafts; for, if the shaft be very short, the amount of twist will only be limited by the ultimate strength of the material, but in ranges of shafting of considerable length, the angle of torsion must necessarily be confined within certain limits, depending upon the degree of accuracy of motion, requisite in the particular instance. In the first case it is usually the strength of journal which is to be determined, for the journal being of sufficient diameter to resist the force applied to it tangentially, the body part of the shaft will be in no danger of rupture from that cause, since it has at least equal strength, and is not subject to wear; and, moreover, the ultimate strength must obviously, as respects torsion, be independent of the length—provided, indeed, the length be not less than the diameter of the shaft. For shafts of which the lengths are small, and in which the angle of torsion may consequently be neglected, we have the following rules:

I. *For solid shafts to resist torsion.—Equations* (S) *and* (T). Find the pressure in lbs. acting upon the shaft at the circumference of the wheel or pulley receiving or transmitting the power: multiply that pressure by the radius of the wheel or pulley, that is, by the leverage at which it acts; if the shaft be cast-iron, divide that product by 125, but, if malleable iron, divide it by 140; and extract the cube root of the quotient; this root expresses in inches the diameter of shaft corresponding to the given pressure and leverage.

II. *For hollow cast-iron shafts, the thickness of metal being* 1-5th *of the diameter—Equation* (W). Find, as before, the product of the pressure and leverage: divide that product by 109, and take the cube root of the quotient as the required diameter in inches.

For particular cases in which a different thickness of metal is employed, the equation, of which the rule is only another form of expression, must be reduced to find the proper divisor. Thus, supposing the thickness of metal to be fixed at 1-7th of the diameter, then

$$n = \frac{d - 2\,t}{d} = \frac{5}{7}; \text{ and } n^4 = \frac{625}{2401};$$

$$\text{therefore, } 125\,(1 - n^4) = 125 \times \frac{1776}{2401} = 92 \cdot 5;$$

which must be taken as the divisor instead of 109 when the thickness of metal is reduced from 1-5th to 1-7th of the diameter of the shaft.

These rules are necessary and sufficient to determine the strength of short shafts to resist twisting, and, consequently, ought to be employed in calculating the strength of journals; but in shafts of great length in comparison with their diameters the angle of torsion becomes an important element in the investigation.

Now, if the extension which the material will bear by twisting without injury when the length is taken as unity be assumed,

$$\text{For cast-iron} \quad . = \frac{1}{1200}$$

$$\text{For wrought-iron} = \frac{1}{1400}$$

then the value of θ in our fundamental equation, that is, the angle of torsion, will be,

$$\text{For cast-iron} \quad . \quad \theta = \frac{2284\ L}{1000\ d}$$

$$\text{For wrought-iron } \theta = \frac{1965\ L}{1000\ d}$$

in which L is the length of the shaft in feet; d the diameter in inches; and θ the angle of torsion in degrees of a circle.

The rule, moreover, indicates the condition that the angle of torsion is as the length directly, and the diameter inversely; and may, therefore, be adjusted with precision to the degree of accuracy with which the motion of the first mover must be transmitted.

Taking the modulus of elasticity of the two varieties of iron at the same values as before, our fundamental rule becomes, for round shafts of

$$\left.\begin{array}{ll}\text{cast-iron and solid } d^4 = & \dfrac{L\,R\,W}{53{\cdot}5\,\theta} \\ \text{“ \quad and hollow } d^4 = & \dfrac{L\,R\,W}{53{\cdot}5\,\theta\,(1-n^4)}\end{array}\right\}\text{......} \quad (S)$$

$$\left.\begin{array}{ll}\text{wrought-iron and solid } d^4 = & \dfrac{L\,R\,W}{71{\cdot}3\,\theta} \\ \text{“ \quad and hollow } d^4 = & \dfrac{L\,R\,W}{71{\cdot}3\,\theta\,(1-n^4)}\end{array}\right\}\text{......} \quad (T)$$

The data usually attainable in practice are the power which the shaft is required to transmit, the leverage at which the power acts, and the length of the shaft; it then remains to fix the degree of torsion which may be permitted without injuriously affecting the regularity of the motion: these quantities being settled, the rules expressed by (S) and (T) for solid cylindrical shafts are thus applied:

Multiply the power in lbs. by the leverage at which it acts, and by the length of the shaft, both in feet; divide the product obtained by 53·5 or 71·3 times the number of degrees in the angle of torsion allowed, according as the shaft is of cast or wrought iron; and the fourth root of the quotient will be the diameter of the shaft in inches.

Thus, by a line of shafting of 40 feet length, the power transmitted is 500 lbs. acting at the circumference of pulleys of 1 foot radius: required the diameter so that the angle of torsion shall not exceed 2 degrees at the extremity, the shafts being wrought-iron?

$$\left.\begin{array}{r}\text{Here } 500 \times 40 \times 1 = 20000 \\ \text{and } 71{\cdot}3 \times 2 = 142{\cdot}6\end{array}\right\} \text{ then } \frac{20000}{142{\cdot}6} = 140{\cdot}25.$$

And the fourth root of 140·25 is 3·44, so that the shafting would be made $3\frac{1}{2}$ inches diameter—which is the actual case.

The rule for hollow shafts differs from that given only in this, that the thickness of metal in relation to the diameter must be assigned as before explained; and for square shafts, the rule differs only in having different coefficients of the angle of torsion.

These rules are sufficient to meet all the cases of calculation which occur in practice relative to the strength of shafts; but the mode of expression often causes considerable previous computation to determine the value of the power transmitted in lbs., as here required. The more common and convenient mode is, therefore, to estimate the strength and sizes of the shafting by the horse-power transmitted, and the velocity. According to this measure, from what has already been explained in respect of velocity, it will be perceived that the resistance must be estimated as the horse-power *directly*, and as the number of revolutions *inversely*, since, with a given power, the velocity must be greater, as the resistance is less. Thus, the resistance due to 32 horse-power on a journal making 50 revolutions per minute will strain it to the same, and only to the same extent, as the resistance due to 16 horse-power acting on a journal which makes only 25 revolutions in the same unit of time; for $\frac{32}{50} = \frac{16}{25} = {\cdot}64$. And, in all cases, when the horse-power, divided by the velocity, gives the same quotient, the stress is the same.

If the rule contained in equation (S) for cast-iron shafts be reduced to the notation corresponding to the dynamical unit of power, it assumes the form,

$$d^3 = \frac{H}{n} \times \frac{25{\cdot}5\,L}{\theta} \text{........................} \quad (U)$$

in which H represents the number of horse-power transmitted by the shaft, and n the number of turns which it makes in a minute; L and θ are respectively the length and angle of torsion expressed in feet and degrees as before. From the rule in equation (T) for wrought-iron shafts we have the form,

$$d^3 = \frac{H}{n} \times \frac{20\,L}{\theta} \text{........................} \quad (V\,C)$$

These rules will apply to the ordinary kinds of shafting, and where it is necessary to keep the amount of torsion in view; but, in cases where less exactness is required, the simpler rules furnished by Robertson Buchanan may be adopted. These rules are intended to comprehend three classes, as—1st. Steam-engine fly-wheel shafts; 2d. Shafts in immediate connection with water-wheels; and 3d. Shafts for ordinary internal mill-geering. The following are the rules:

$$\text{1st class} \quad d = \sqrt[3]{\left\{\frac{H}{n} \times 400\right\}}$$

$$\text{2d class} \quad d = \sqrt[3]{\left\{\frac{H}{n} \times 200\right\}}$$

$$\text{3d class} \quad d = \sqrt[3]{\left\{\frac{H}{n} \times 100\right\}}$$

These rules are stated to be derived from “observation of shafts in actual use, and of acknowledged

good proportions;" and for short shafts, they express pretty nearly the practice of some of our best millwrights; but, in his last edition of the Essays on Mill-work, the rule for cylindrical cast-iron shafts is

$$d = \sqrt[3]{\left\{ \frac{H}{n} \times 240 \right\}}$$

Couplings.—Couplings are of necessity employed in a line of shafting when of greater length than is found practicable to cast or forge in one continued shaft. They are also frequently required in cases where one length of the shaft would suffice, for the purpose of occasionally disconnecting parts of the geering beyond a certain point of the line; and likewise for connecting and disconnecting particular machines.

The most simple species of connection is the square coupling. In this the end of the shafts to be connected are made square, and are embraced by a square *coupling-box*, the internal surface of which is fitted exactly to the squares of the shafts. A box is divided into two parts, which close together diagonally upon the shaft, and are provided with flanges at their junction, by means of which they are bolted together, and to secure the shafts, so that one cannot turn without driving the other. The coupling is sometimes made quite plain; embracing the shafts like the one now described; and, when occasion requires it, the box may be slipped back on one shaft, to leave it clear of the other, thereby admitting of the motion being discontinued, or of one or both being removed for repairs or alterations.

An objection to this arrangement of a rigid square coupling at once suggests itself, when we reflect that, although the motion would go on all very smoothly so long as the shafts remained mathematically true to each other, when the one of them wears down in its bearings faster than the other, or when the wearing is in different directions, it must follow, that in some part of the revolution the shaft is lifted off its bearings, where there are two bearings, one on each side, and unsteady motion is produced, together with further straining and wearing of the couplings. This objection, it is true, applies principally to the shafts of heavy mill-work; but it is only for such purposes almost exclusively that this form of coupling is employed; in small machinery it is only occasionally employed.

A variety of the square coupling consists in having fitting-strips, or projections along the corners of the square parts of the shafts. The square form of the shaft is in this case virtually preserved, and there is the advantage of the coupling being fitted with greater facility, while the strain is concentrated upon the corners of the shaft.

The round coupling is, in some respects, open to the same objections as the square coupling. It will be understood from Fig. 2086, which represents it in section. In this the ends of the shafts are made cylindrical, and meet together, with flat ends, under a round coupling fitted truly upon them, and secured to them by pins *a* and *b* at right angles to one another. This joint may be made with greater precision and much less expensively than the other, as the parts may all be accurately turned and fitted together. It is clear, however, that, as the strain is concentrated on the pins and holes, these parts must wear out soon; at the same time, it is easy to renew the pins, though, obviously, they cannot be made to fit the holes so accurately as they did at first. This coupling is not often used for heavy shafting, on account of the objection just stated, though we think it might readily be applied to lighter shafts.

2086.

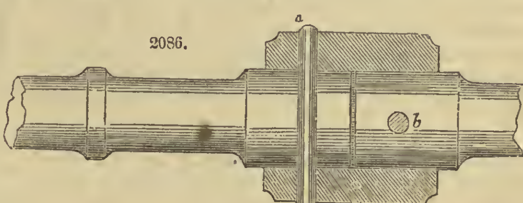


Fig. 2087¹ is a rigid sleeve coupling for a cast iron shaft; it consists of a solid hub or ring of cast iron, hooped with wrought iron; the shafts are made with bosses, the coupling is slipped on to one of the shafts, the ends of the two are then brought together; the coupling is now slipped back over the joint, and firmly keyed. This is an extremely rigid connection. Fig. 2087² is a screw coupling, a very neat and excellent rigid coupling, for the connecting of wrought iron shafts, more especially the lighter kinds. It will be observed that this coupling admits of rotation but in one direction, the one tending to bring the ends of the shafts towards each other, the reverse motion tends to unscrew and throw them apart, and uncouple them.

2087¹

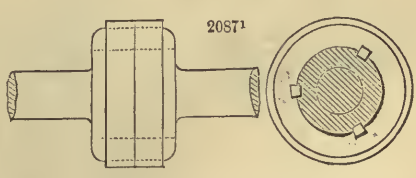
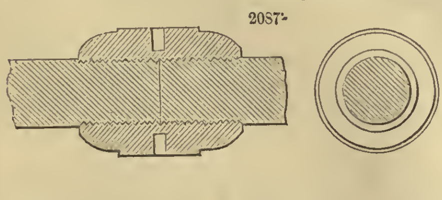
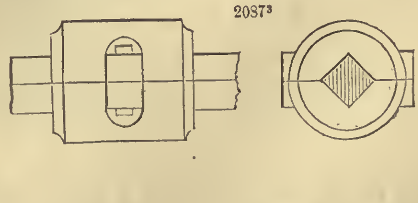


Fig. 2087² is a clamp coupling for a square shaft.

2087²



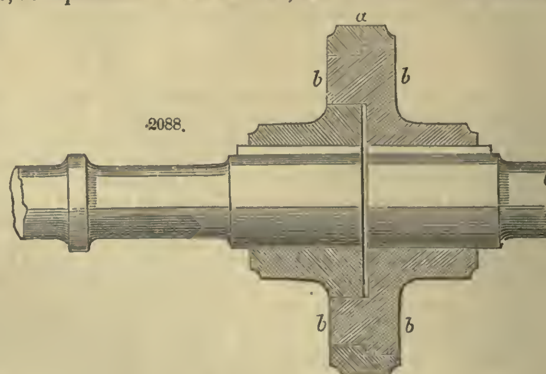
2087³



The coupling shown in figs. 2088 and 2089 is constructed of two cast-iron plates, *a a* and *b b*, keyed one on the end of each of the shafts. The plate *a* is formed with two segmental openings in it, which will be better understood from fig. 2089 at *c c*; these openings are intended to receive corresponding

projections on the face of the plate b, as represented in the section; and thus the shafts become engaged. The rim of the plate a overlaps and embraces the circumference of the other plate, and thus they are preserved exactly concentric.

2088.

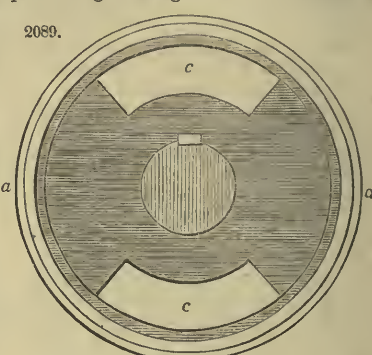


This coupling, applicable to shafts with two bearings, one on each side of the coupling, is simple and durable. It is easly adjusted, and may be disconnected without difficulty.

Fig. 2090 is another combination of disks suitable for couplings with only one bearing. The disk b is keyed on one shaft, and is recessed on the face, to receive the smaller disk c; this disk is sunk flush with the face of the other, and is screwed tightly up to it by means of the ring a, which is bolted to the disk b, and secures that marked c. Between the three plates, a, b, and c, annular pieces of leather are interposed, which bring them all to a proper bearing.

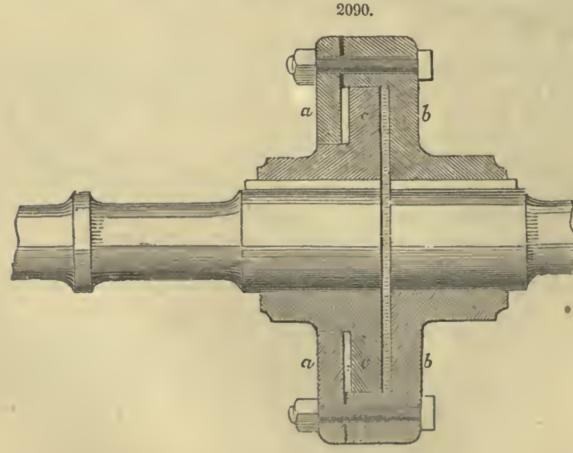
This combination, termed a friction coupling, is useful for preventing breakage of the connections in case of a sudden stoppage or reversal of the motion. It is plain that the holding power of the coupling depends simply upon the tightness with which the disks are screwed together, and the consequent frictional force of the surfaces of leather and metal.

2089.

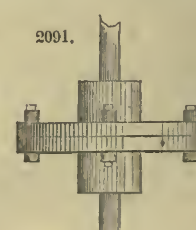


Of late years, in this country, turned wrought-iron shafts have been very generally adopted in manufactories and workshops: the coupling in most common use for connection is the faced coupling, Figs. 2091 and 2092. This coupling consists of two parts, one of which being firmly keyed to the end of each of the shafts to be connected, the faces are then brought together, and securely united by bolts. In fitting this coupling, considerable care is requisite. Each part of the coupling is first turned and drilled, then driven hot on to its shaft, reduced a little in diameter to receive it, or forced on by screws. It is then strongly secured by a key or keys to the shaft. The shaft is now put into a lathe, and the coupling is faced; that is, the faces of the coupling which are to be bolted together are turned, so that they are perfect planes, at right angles to the shaft. The bolt-holes on the two portions should correspond exactly. They are therefore drilled on a chuck, with an index; the holes are made slightly tapering, and the bolts, fitting tightly, are driven in by smart blows of a hammer, and secured by nuts. Faced couplings, thus fitted, afford com-

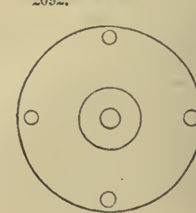
2090.



2091.



2092.

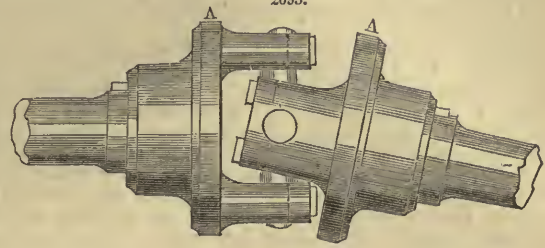


plete and firm connections. The chief objection to their employment lies in their stiffness or rigidity They are, therefore, mostly used to connect wrought-iron shafts, when the elasticity of the shafts obviates the inconveniences resulting from little, and sometimes unavoidable, settlements or inequalities of the bearings.

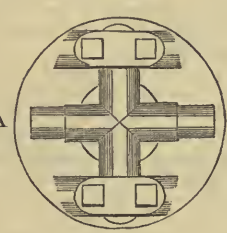
Another form of permanent coupling is that known as Hooke's Universal Joint, from the name of

the inventor, Dr. Robert Hooke. The object of this coupling is to unite shafts which are inclined to each other in the line of direction, and which do not, therefore, admit of being rigidly connected, as in ordinary cases. This coupling is very commonly employed in light machinery, as in steeple clocks, for taking off the index-motion, and is then usually constructed by forming an arc on the two extremities which it is intended to connect, and to form the joint by a central cross $b\overset{a}{\underset{a}{+}}b$. the extremities of the ark on the end of one shaft being jointed to the arms *a a*, and the extremities of the arc on the other shaft on the arms *b b*, at right angles to the former. But this simple mode of construction is not adequate to the purposes for which the coupling is required in a line of shaft-geering; in this case, although the principle is not in any way changed, the construction is much more substantial. Figs. 2093 and 2094 represent a form of it adapted to heavy strains. A is a strong disk keyed on the end of each shaft carrying a pair of bearings for the reception of the gudgeons formed on the extremities of the cross. Fig. 2094 is a face view of one of the disks, showing the cross in its place, with its alternate journals disengaged.

2093.



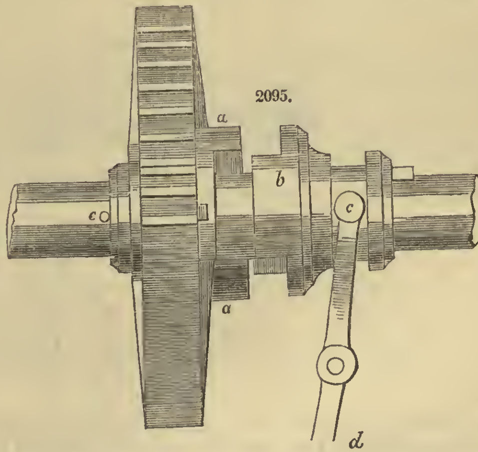
2094.



In this illustration the shafts are shown at nearly the limit of the angle to which the single joint ought to be applied. This angle ought not exceed fifteen degrees; when a higher angle is introduced, the rotatory motion becomes very sensibly irregular, and the friction is greatly increased. This defect may be obviated by using a double joint.

With the view of admitting the disengagement of the connection, in cases of sudden stoppage or reversal, the coupling, Fig. 2095, is sometimes employed. In this instance, the shaft is supposed to be continuous, and the coupling may be termed a *disengaging coupling;* *a* and *b* are the two parts of the coupling, formed on the acting faces into alternate projections and recesses, such as they correspond with, and exactly fit into each other when in geer. The part *a* is, in this example, cast on a spur-wheel, from which the motion of the shaft is supposed to be taken off. Both of the parts *a* and *b* are, to a certain extent, loose on the shaft; the former being capable of moving round on it, though deprived of longitudinal motion by washers and pins marked *e*, and the latter being free to slide on the shaft, though prevented from turning on it by a sunk key, which slides in a slit inside the *clutch* or sliding piece *b*. The mechanism is put into geer by means of the handle *d*, which terminates in a *fork* with cylindrical extremities *c*, and it is obvious, that by the contact of the flat faces of *a* and *b*, the latter will immediately carry with it the other part at the same speed as the shaft. Supposing, now, that the motion of the wheel *a* is suddenly accelerated, the oblique faces of the couplings immediately fall out of contact, and slide free of each other, leaving the couplings clear, and the shaft free to continue in motion.

2095.



In the old form of this contrivance, known as the sliding bayonet clutch, the part *b*, instead of the tooth-like projections on the face, had two or more prongs which laid hold of corresponding snugs cast on the face of the part *a*—which, moreover, was usually a broad belt pulley introduced with a view to modify the shock on the geering on throwing the clutch into action. In an older form still the pulley was made to slide end-long on the shaft. A form analogous to this was known as the "lock pulley." Instead of the end-long motion common to the other modes, the parts were "locked" together by a bolt fixed upon the side of the pulley, and which, when shifted towards the axis, engaged with an arm of a cross, of which the part *b*, in Fig. 2095, is the modern representative. The bolt was wrought by means of a key and stop, the turning of the key throwing back the bolt, and thereby unlocking and disengaging the pulley.

The form of coupling represented by Fig. 2095 is particularly applicable when the impelling power

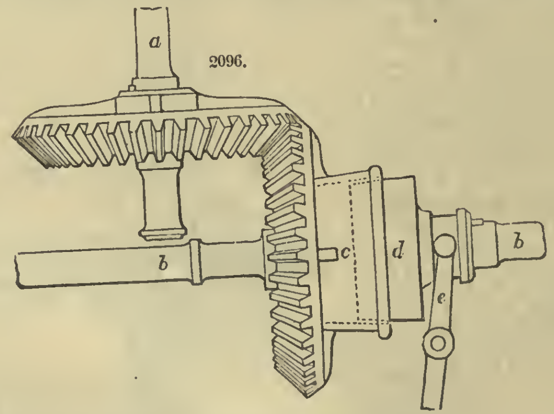
is derived from two sources—a circumstance which frequently occurs in localities affording water power to some extent, and yet not in sufficient abundance for the demands of the work. The deficiency is usually supplied by a steam-engine; and the two powers are concentrated in the main line of shafting by a coupling of the kind depicted. In cases of this kind, the speed of the shafting being fixed, and the supply of water inconstant, the power of the water-wheel ought to be thrown upon the wheel *a a*, and that of the engine upon the shaft at another point. By this arrangement, the speed of the line can be exactly regulated by working the engine to a greater or less power, according to the supply of water. The proper speed of the water-wheel will likewise be maintained, which is of importance in economizing the water power.

The same form of coupling is also used occasionally for engaging and disengaging portions of the machinery. But for this purpose the object is to obtain a mode of connection by which the motion may be commenced without shock; for it is a law in mechanics that when a body is struck by another in motion, some time elapses before it is diffused from the point struck through the other parts; consequently, if the parts receiving the blow have not sufficient elasticity and cohesive force to absorb the whole momentum of the striking body till the motion be transmitted to the centre of rotation, fracture of the body struck must necessarily ensue. Hence, in a system of mechanism, any parts intended to be acted upon suddenly by others in full motion ought not only to be strong, but they ought to be capable of yielding on the first impulse of the impelling force with as little resistance as possible, and gradually bring the whole weight into motion. The common mode of driving by belts and pulleys accomplishes this object very satisfactorily. In this the elasticity of the belt comes into action; and should this be inadequate, it has the liberty of slipping on the pulleys, till, by the friction between the sliding surfaces, the belt gradually brings the quiescent pulley into full motion. This mode of connection is unexceptionable when the power to be transferred is not great; but its application to large machinery is attended with inconvenience.

When the belt connection is employed, the provision of the fast and loose pulley is the most simple and effective form yet devised for the purpose. It consists simply of two pulleys in juxtaposition on the same axis—the one fast, and the other loose, so that the belt which transmits the motion may be shifted at pleasure upon one pulley or the other, by that means putting in or out of motion the axis upon which they are placed. The driving pulley—that is, the pulley on the shaft from which the motion is derived—ought to be equal in breadth to the two on the second shaft; and these last ought to have their rims slightly rounded or swelled in the middle to prevent the belt slipping off—which it is apt to do when the rims of the pulleys are flat. This curious property is of great practical importance, and has obviated all those clumsy appendages formerly required to keep the belt from being thrown.

This mode of driving is not, however, always convenient; and, accordingly, many attempts have been made to accomplish the same with wheels. Perhaps the best of these is the method of friction cones,

2096.



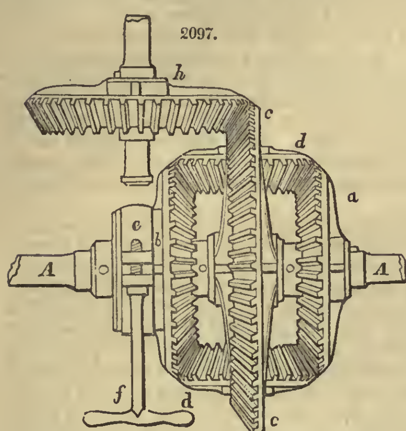
represented in Fig. 2096. The two parts of this coupling, *c* and *d*, are arranged on the shaft *b*, in the same manner as we have described under the preceding figure. *a* is a shaft driven by means of bevel-geer off the main shaft *b*, its motion being derived from the latter shaft through the coupling. *c* is an interior cone cast upon the back of the bevel-wheel; *d* is an exterior cone having the same taper as the cone *c*, such that by means of the handle *e* it may be moved into contact with the interior cone. The surfaces being supposed to be well fitted to each other, the cone *d* will, by its friction, drive the cone *c*, and thereby also the upright shaft. When either of the shafts *a* or *b* is accidentally stopped, the cones immediately fall out of geer, and the connection is broken. They are held in geer by means of a screw, or more commonly, and perhaps better, by a weight.

This coupling works very well, if properly adjusted at first; but requires some nicety in communicating the exact degree of taper to the cones; for if, on the one hand, the taper be too small, they are liable to adhere into each other too firmly, and on the other hand, if the taper be too great, they do not possess sufficient frictional force to keep them in contact.

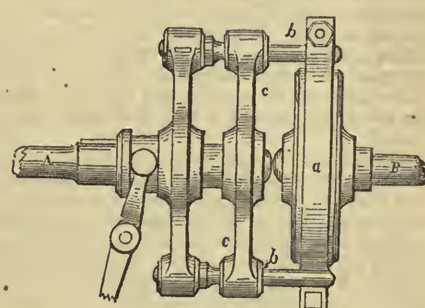
Another mode of accomplishing the same purpose in small machinery, by means of an epicyclic train, is represented by Fig. 2097. In this the shaft A A is continuous, and supposed to be that through which the motive power is transmitted. The wheel *a* is fast, but those marked *b* and *c* run loose on

this shaft. The two pinions *d d* have their bearings *in* the wheel *c c*, and geer with the two opposite bevel-wheels, *a* and *b*. (One of these pinions only is requisite to complete the motion; the second being introduced merely to maintain the equipoise of the system.) If now motion be given to the shaft A A, it is clear that the wheel *b*, which is loose, will be made to revolve in the contrary direction to the wheel *a* which is fixed, by means of the carriers *d d*; but no motion of the wheel *c*, *if slightly opposed*, will ensue; and so long as this last remains at rest, the wheels *a* and *b* will have the same angular velocity in opposite directions. But if the motion of the wheel *b* be opposed by means of a friction gland *e*, which can be tightened by means of the T-screw marked *f* to any degree required, the teeth of that wheel will serve as fulcra to the carrier pinions *d d*, which, becoming levers of the second kind, with the resistance at their axes, they will carry round the wheel *c* with half the velocity of the prime mover *a*; and geering with the wheel *h*, on the main spindle of the machine to be impelled, will transfer to it the motion which itself receives. We have supposed the wheel *b* to be held absolutely still; but it is obvious that it may be brought gradually to rest by means of the friction gland; and as the wheel *c* can attain motion only as the motion of the wheel *b* is reduced, and can attain its full speed only when *b* is brought to rest, it is clear that the wheel *h*, and, consequently, the machine, may be brought into action without the slightest degree of shock; and, moreover, may be driven at any velocity less than the maximum, that may be desired.

2097.

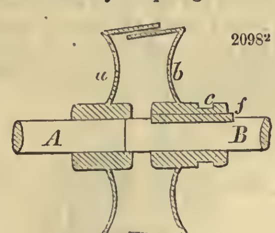


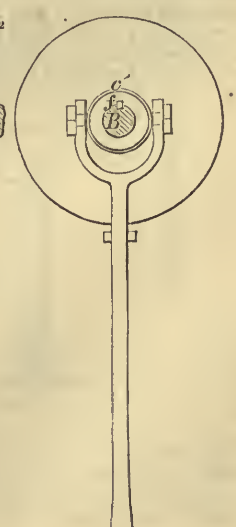
2098.



Another mode of obviating shock in starting machinery, which has been long in use, is represented by Fig. 2098. On the shaft B is fixed a drum or pulley which is embraced by a friction-band *a* as tightly as may be found necessary; this band is provided with projecting ears, with which the prongs *b b* of a fixed cross on the driving-shaft A can be shifted into contact. This cross can be shifted end-long on its shaft A, but is connected to it by a sunk key, so that being thrown into geer with the ears of the friction-band, the shaft being in motion, the band slips round on its pulley until the friction becomes equal to the resistance, and the pulley gradually attains the motion of the clutch. The arms and sockets *c c*, which are keyed firmly on the shaft A, are used to steady the prongs and to remove the strain from the shifting part.

2098²





But of all slide couplings to engage and disengage with the least shock, and at any speed, the *friction cone* coupling, (fig. 2098².) is by far the best. It consists of an exterior and interior cone, *a b*; *a* is fastened to the shaft A, whilst *b* slides in the usual way on the feather *f* of the shaft B; pressing *b* forward, its exterior surface is brought in contact with the interior conical surface of *a*; this should be done gradually; the surfaces of the two cones slip on each other till the friction overcomes the resistance, and motion is transmitted comparatively gradually, and without danger to the machinery. It must be observed that the longer the taper of the cones, the more difficult the disengagement; but the more blunt the cones, the more difficult to keep the surfaces in contact. The limiting angle of resistance for surfaces of cast-iron upon cast-iron is 8° 39′, and this angle with the line of shaft will give a very good angle for the surfaces of the cones of this material. When thrown into geer, the handle of the lever or *shipper* is slipped into a notch, that it may not be thrown out by accident.

For the engaging and disengaging of a machine, that is, for putting into or out of motion, the arrangement of a *fast-and-loose* pulley is adopted as simpler and better than the clutches before given; it is almost invariably used in connection with single machines which may be required to be thrown in and out of motion. It consists merely of two pulleys in

juxtaposition on the same axis, one fast, the other loose, so that the belt which transmits the motion may be shifted from one to the other. The face of the driving pulley, that is, the one on the driving shaft, ought to be equal in width to that of both the fast and loose pulleys. By making the face of the pulleys slightly convex, the belt is prevented from slipping off, as the tendency of a belt is always to the larger diameter.

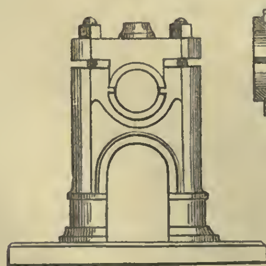
Bearings.—Another important feature in a system of mill-geering is the mode of supporting the shafting—the form, arrangement, and general adaptation of the plumber-blocks and steps, and their supporting apparatus. These are manifold in their proportion and construction—depending, as they do, in a great measure, on the taste of the engineer and the circumstances in which they are employed. Even the length of journal in relation to its diameter is far from being a fixed quantity; and as the journals determine the length of the *pillows* or *brasses* employed, these last are equally indefinite in their proportions. The range of variation is gradually becoming less as the principle of friction is becoming better known; but still we find journals made equal in length and diameter; and others having a length equal to their circumference. These proportions, except for particular cases, are extremes to be avoided.

Without attempting to establish a general rule for the length to be given to bearings, under all circumstances, it may be observed, that the pressure upon the pillows or steps ought in no case to exceed 1,000 lbs. on the square inch of rubbing surfaces. Within this limit the wear of the brasses is moderate; but, when a less intense pressure can conveniently be attained by increasing the amount of surface, without a countervailing evil, it ought to be adopted, even to half the pressure stated. To calculate every particular case which occurs in practice, and to adapt the patterns to it, would, however, be attended with an amount of labor and expense which it is found necessary to avoid; and, accordingly, the mode commonly adopted is to fix upon two extreme cases, and to proportion the intermediate lengths to these. Thus, taking a journal of 2 inches diameter, and another 12 inches; and suppose 4 inches to be taken as a proper length for the former and 19 inches for the latter; then the lengths for intermediate diameters may be assigned by arithmetical progression. Thus, between 2 inches and 12 inches there are 40 *quarters*, and between 4 inches and 19 inches there are 120 *eighths;* consequently, for every increment of $\frac{1}{4}$ inch of diameter, we have a corresponding increment of $\frac{3}{8}$ inch of length of journal.

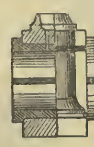
The common material employed for pillows is a composition of copper and tin, in the proportion of 12 to 1. This alloy is much harder than common brass, and is supposed to work with cast and wrought iron with less friction, and to be more durable than most other compounds. Cast-iron pillows, especially when cast in iron moulds, and when the rubbing surfaces are made large in proportion to the pressure upon them, are not inferior in any respect to the bush-metal commonly employed—the friction is, indeed, rather less than greater, and being harder, they are still more lasting. But when the pressure is so great as to produce abrasion of the surfaces when left occasionally without a proper supply of oil, the wearing process, thus commenced, goes on increasing, and the surfaces never afterwards acquire the necessary polish. In this the bush-metal has an advantage, for although abrasion has proceeded a certain way, when the lubrication is again perfect, the pillows take a new polish as perfect as before, and the abrasion ceases. Wooden pillows are also sometimes employed with advantage. Box-tree and lignum vitæ were long in use, but those woods, besides being much more expensive, are far inferior for the purpose to home-grown beech. We have known journals which, with ordinary metal pillows, were ever liable to heat, run for many years on beech-wood without manifesting any tendency of that kind.

Pure tin is, perhaps, of all other substances, that which produces the least friction with iron; but its softness has prevented it being very extensively employed. When the pressure upon the rubbing surfaces exceeds very moderate limits, the tin yields to it, and becomes extended in the direction of the length of the pillow. A mode of obviating this difficulty has been patented in the United States by Mr. Babbitt; it consists in placing the soft metal in a species of casing of cast-iron, of the common form of the half pillow, but with ledges round its concave surface, which thus presents a recess of a depth corresponding to the size of the pillow—from $\frac{1}{8}$th inch to an inch in very large diameters. This recess is filled with the soft metal, which is retained by the ledging of the casing, and prevented from yielding and becoming extended by the pressure on its surface.

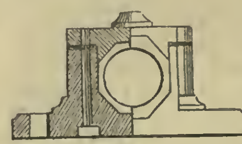
2102.



2101.



2099.



2100.

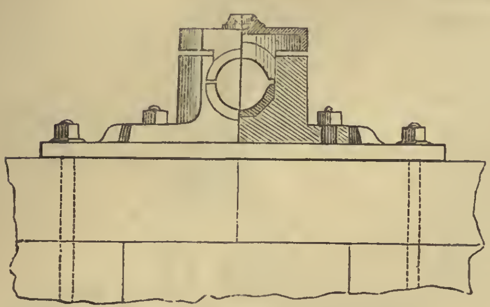
The material used by Mr. Babbitt is not pure tin, but a soft alloy, in which lead predominates, and which, besides answering all the purposes of tin, has the advantage of being greatly cheaper.

A patent for a composition-metal has lately been obtained by Mr. Fenton; it is harder than Mr Babbitt's metal equally fusible, and still cheaper, and has been found very efficient as bush-metal in

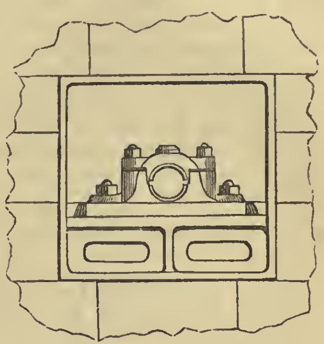
railway engines. It is simply a compound of tin and zinc, with a little copper to harden it; and a very excellent composition of the sort may be made of equal parts of the two former metals and a sixteenth by weight of antimony to give hardness.

Forms of plumber-blocks and pillows, very commonly adopted for heavy shafts, are shown by Figs. 2099, 2100, 2101, and 2102. In this the pillows are made octagonal to prevent their turning round with the shaft, and are cast with flanges on their ends to prevent longitudinal displacement. This form has, however, been departed from by some of our best millwrights. Instead of casting the brasses with flanges and plane faces, they are cast of a cylindrical form, and with two snugs at the middle of their length, which, entering corresponding recesses in the plumber-block, retain them securely in their places when the cover is fixed. By this arrangement they are more easily fitted, contain less useless metal, and have a lighter appearance. The plumber-block itself, also, admits of being bored out to the size of the pillows; whereas, with the octagonal form, the faces require to be planed to the required angles—a much more expensive process.

2103.

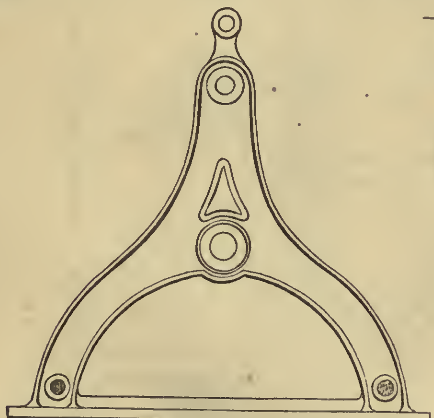


2104.

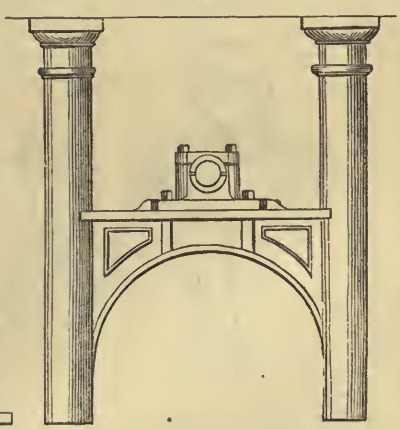


The plumber-block consists of a sole and cover, which, when practicable, are independently bolted together, the heads of the cover-bolts being countersunk in the sole. The cover is made to check accurately within the cheeks of the block, the surfaces being planed true to each other, so that the stress upon the bolts is reduced to a minimum. The sole has two projecting ends by which to bolt it in its place, as shown in Fig. 2103, and elsewhere. The figure specified is an example of a plumber-block with what is denominated a *false* or *shell* cover—a form often adopted for economy when the pressure is entirely down. In this case there is only one brass, the cover part being cast with side projections resembling the ends of a brass, and with projections on its upper surface resembling the nuts and ends of bolts of the regular form represented by Fig. 2099. This cover is not fitted, but is simply laid loosely in its place, and serves merely to preserve the journal from sand and similar injurious matters.

2105.



2106.

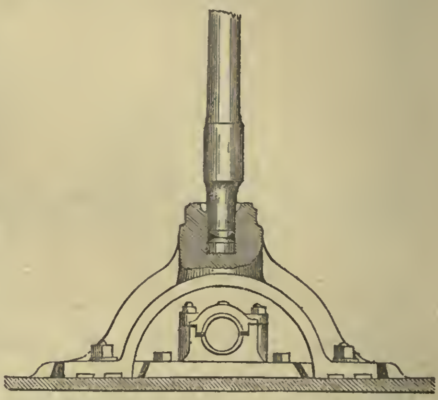


The form of pedestal represented under the footstep-bridge by Fig. 2107, is one of the best examples, combining strength, elegance, and simplicity of make. It is in every way appropriate for its purpose. The base and cover fit together with a degree of symmetry and character which are not found in the examples above referred to; and the amount of fitting is much reduced. The base and cap being checked together by planing, they are fixed in their relative position by the cover-bolts, and bored out to the extreme diameter of the brasses. But instead of a uniform concave surface, the interior of the base and cap have a circular recess of small depth occupying about a half of their breadth, so that the bored parts occupy about a fourth of the breadth of the concave surface on each side of this recess the object of this is to avoid the necessity of turning the exterior of the brasses for an equal extent at the middle of their length, and, therefore, allows of their being provided with snugs as already noticed,

to secure them from turning round in their places with the journal. The brasses being turned to fit their position in the pedestal, they are bored out concentrical with the outer circle; and the points of the cap-bolts and the nuts being dressed, the plumber-block is ready to be bolted in its place.

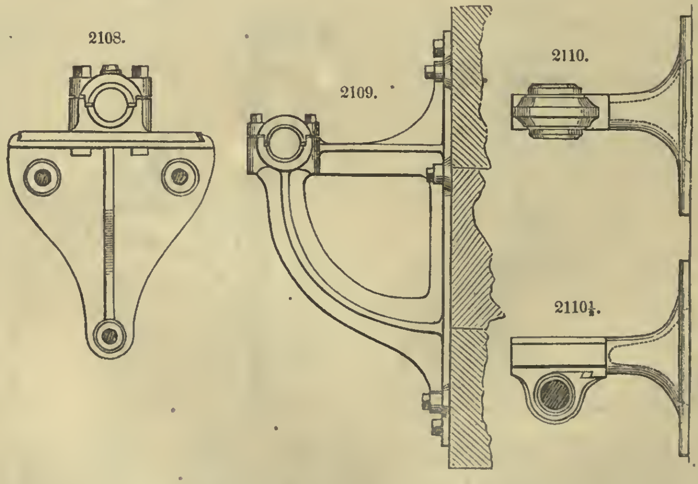
The foundation-plate, upon which the sole of the pedestal rests, is usually provided with *snugs*, set so much apart as to allow of a wooden *key* being driven between them and the ends of the pedestal-sole. The bolt-holes in the sole and foundation are also made oblong, to allow of a small amount of adjustment in setting the pedestal; and, to obtain this latitude of adjustment laterally, and also in the direction of the axis of the brasses, the holes are lengthened in the sole and foundation in the corresponding directions. Adjustment is attained vertically by allowing for a given thickness of wood to be placed under the sole of the pedestal, and which can be increased or diminished at pleasure to obviate any small inaccuracy of workmanship.

2107.



In ordinary mill-work pedestals are usually provided with some form of cast-iron foundation-plate upon which they are fixed. This is exemplified by Figs. 2103, 2104, 2106, 2108, and 2107; and it frequently happens that much ingenuity is necessary to *compose* what is technically denominated a *wall-box* or *fixing* for the proper reception of the number of pedestals required by a confluence of shafting to a point. Fig. 2104 affords an example of one of the most common and simplest forms of wall-box, being intended to carry only one pedestal for a shaft which may be supposed either to pass through the wall into which the frame is inserted at that point, or to terminate there. If intended to carry the end of a shaft, it is usually made in the form of a rectangular box with the bottom *into* the wall, and with a shelve at a convenient height to receive the sole of the pedestal, the breadth of which determines the depth of the box. But when the shaft passes completely through the wall, the box is simply a rectangular frame, corresponding in depth with the thickness of the wall into which it is inserted and with the cross-shelve, for the purpose before stated. This makes a neat, convenient, and substantial fixing, and one which is in constant requisition.

Fig. 2108 gives an example of a pedestal wall-plate, and which serves the same purpose as the wall-box above described, when the shaft terminates at the wall and does not pass through it. This species of fixing is simply a bracket bolted to the wall by three bolts which pass completely through and are secured on the outside by *wall-washers*, *bonnets*, or *stars*. These are merely plates of cast-iron, sometimes with radial arms to increase the amount of bearing surface, with holes through their centres, to receive the ends of the bolts, which being screwed, are retained by nuts passed over them in the usual manner. Commonly the bolts are entered from the outside, which is generally advisable for conve-



nience and safety. The wall-washers serve the purpose of increasing the amount of surface of the wall acted upon, and thereby allow the bolts to be screwed up more tightly; and the more friable the material of the wall is, the larger these ought manifestly to be made. For brick walls a very common proportion between the size of bolt and bonnet, estimated by diameter, is *one* to *six*. For dressed stone walls, the proportion may be somewhat less; but for rubble work the stellar form ought to be preferred.

The bracket is provided with a projecting sole upon which the pedestal rests, and which is supported

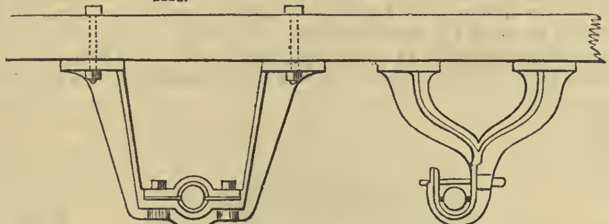
at the middle of its length by a rib cast upon it. The sole has a *snug* at each end, between which the pedestal is keyed, and holes through it to receive the pedestal-bolts.

Fig. 2109 represents another form of wall-bracket. This form is employed for carrying a shaft *along* a wall, and projects sufficiently to allow space for any wheels and pulleys which may be upon the shaft to work clear of the wall. The bearing is in this case formed in the bracket itself, and the cover is held in its place by two bolts secured in the cheeks of the block by cotterals.

As this species of bracket does not allow of any adjustment at the bearing, and as it would be difficult to adjust, if fitted directly upon the wall, it is usually provided with a *wall* or *ground-plate*, as shown in the figure. This plate is, in the first place, secured to the wall by wall-bolts and washers, in the manner above described; and the bracket is then adjusted and fixed upon it by bolts and keys, in the same manner that the simple pedestal is secured to its seat. But sometimes, and judiciously, its bolts also pass entirely through the wall, and serve to maintain the stability of both foundation and bracket.

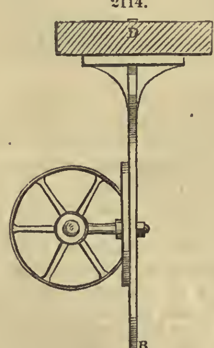
Figs. 2110 to 2112 are forms of pendent brackets intended to carry lines of shafting along the ceiling of a building. Fig. 2111 is the simplest form, and is often used to carry the weight of the shaft at points intermediate to those at which the power is taken off, but sometimes also it is the only species of bracket employed when the shafting is light. It is easily fitted, and has very commonly only an under pillow for the shaft, and no cover; but when the shaft has an upward pressure—which it must at any point where motion is transferred to or from it by toothed geer, whose line of contact is in the horizontal plane,—a species of block-brass is fitted into it and retained by a cotter, as shown in the figure. The ends of this block are checked, and the back of it has a groove to receive the edge of the cotter; it is thus effectually prevented from moving on end, and may be forced downwards upon the shaft by advancing the cotter, which is made of a tapering form for that purpose

2112. 2111.



This form of gallows has, however, no other recommendation than cheapness. It is inelegant in the last degree, and deficient in stability, is easily twisted out of position in consequence of the oblique action of the weight upon it; and, moreover, the hook into which the brasses are fitted being usually narrow—another feature of economy always associated with it—the brasses soon become loose and allow a hobbling motion of the shaft, not more unpleasant to witness than it is injurious to all the connections of the line, and to the accurate transfer of the power at the working points.

2114.



2113.

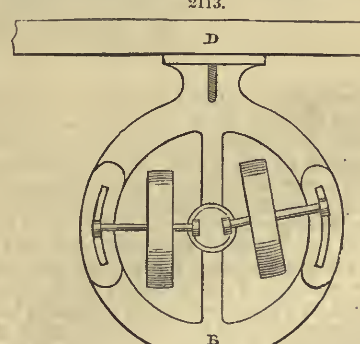


Fig. 2112 represents a gallows of a more substantial character, but still inelegant in appearance, and, in some respects, inconvenient. The weight being equally and directly borne by the two supporting points, it possesses all the advantages of strength; it may be provided with a cover and cover-brass, which are necessary when the bracket is placed in the vicinity of a pair of wheels which geer together. The form of bracket has the manifest inconvenience that the shaft cannot be taken out of its place except by moving it end-long.

Figs. 2110 and 2110½ are two views of a form of pendent bracket, which combines to a considerable extent the two requisites of strength and simplicity. The pillar and expanded base of this bracket are cast hollow, as indicated by the dotted lines in Fig. 2110½. The cover is fitted to the pillar by planed faces which check together, leaving space to receive a bevel-edged key which holds the cover in its place when the stress is entirely downwards; but when the bracket is intended to be placed in the vicinity of two geering-wheels, the cover and projection on which the under pillow rests are provided

with snugs through which a *nib-bolt*, as it is technically called, passes and assists the key in retaining the cover in its place.

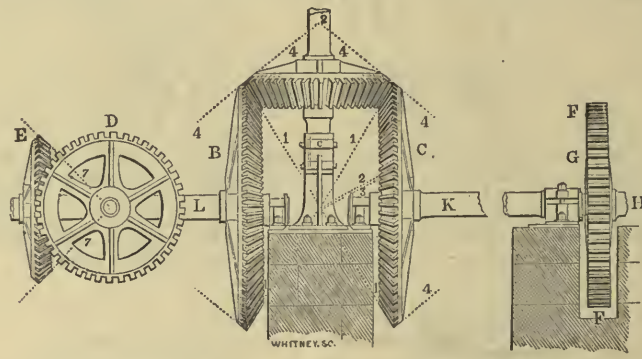
This form of pendent is also convenient to the millwright as a pattern. In the two forms above described, any difference of length is attended with extensive alteration of the pattern, but in this, the stalk of the pattern is made at least as long as there is any probability of its ever being required; a series of ferules are then turned to fit upon the stalk, and of the requisite outside diameter; the necessary number of these are put on to make up the length *less* the length of the octagonal part which forms the bearing; this part is formed of cast-iron, and has also a hole through it to receive the stalk, and when put on and fixed in the proper position the bracket is ready to be moulded, any part of the stalk which may be projecting through being *cut off* in the sand. The process of moulding is likewise simple, and no core-box is required, except when the bracket has a double bearing, which is always the case when it is intended for a point at which a bevel pair meet.

The only objection to this form of bracket is the oblique direction in which the strain falls upon the holding bolts, and which might be obviated by making the cover one piece with the stem, and checking the under bearing to it by a strong dovetail and single holding-bolt, the office of which would simply be to prevent end-long motion.

Pendent brackets such as those here described, are sometimes cast with vertical soles, prepared to bolt to beams; but more frequently the soles are horizontal; and in that case are bolted to *grounds* of planking fixed between two adjoining beams by wood-screws. When the brackets can be attached to beams, that mode of fixing is, however, to be preferred; and in that case the sole ought to be formed with a projecting rib to bear against the under side of the beam, and relieve the bolts as much as possible of strain.

The kinds of bearings described are all designed to support shafts placed horizontally; but in almost every system of geering there is one large vertical shaft from which the minor horizontal shafts derive their motion. The bottom extremity of the vertical shaft is supported on a species of bearing technically named a foot-step, of which Fig. 2107 represents a specimen. In this case, the motion is usually transferred by a pair of bevel-wheels, as represented by Fig. 2001, and more completely still by the arrangement shown in Fig. 2115. In this last the first shaft is marked H; on this is the spur pinion G

2115.



which geers with the equally pitched wheel F on the horizontal shaft K. On the other extremity of this shaft is the bevel-wheel C, which geers with a similar wheel on the vertical shaft; and through this last wheel motion is communicated to the equal wheel B and the geering on the right. The arrangement represented by Fig. 2001 is strictly analogous—the horizontal shaft being the driver and the vertical shaft the carrier of the motion to the superior parts of the factory.

In these arrangements the foot-step of the vertical shaft is carried upon an arch, technically a *foot-bridge*, of which Fig. 2107 gives a front view, and Fig. 2115 a side view: Fig. 2001 shows a section of the same through the foot-step box. This bridge rests on a foundation-plate of cast-iron, which in turn is fixed upon a stone foundation more or less substantial, according to the weight and stress which are to be resisted. The pedestal of the horizontal shaft ought to be supported on the same foundation sole; for, if supported on a separate sole, the foundation bolts, and possibly the foundation itself, will in all probability be soon destroyed by the twisting action of the wheels at the fixed points. The foot-step box occupies the summit of the arch; three sides of it are cast upon the bridge, but the fourth side, which forms the *door*, is a separate casting, attached by four bolts which pass right through from back to front of the box, hollow *rolls* being cast on the two opposite sides for that purpose. In Fig. 2107 the door is supposed to be removed to show the interior arrangement; Fig. 2001 gives a transverse section through the door, showing its thickness; and Fig. 2115 shows the door in its place and fixed by its bolts. This door is fitted with great exactness, and the whole interior of the box—at least a sufficient bearing surface of it at the angles—is chipped and filed true: a foot-plate as in Fig. 2001, and sometimes a species of box solid above, and sometimes both, is fitted into the bottom of the box. This plate or pillow is first planed; and in fitting, its superior surface is set truly square with the sides of the box. The surface of the plate is frequently steeled by case-hardening when the end of the shaft is intended to be rested immediately upon it, as shown in the drawings referred to; but more commonly it is simply a plate of cast-iron on which the bottom of the cup-formed brass is supported. In these drawings the brass is supposed to be without bottom, and to embrace the cylindrical end of the shaft, and support it laterally. This arrangement has its advantages, in so far as the foot-plate can easily be

replaced when worn out; and the brass may be formed in halves, which will allow it also to be replaced with little difficulty. But more commonly the brass has the form of a deep cup, interiorly; while, exteriorly, it is made in size exactly to fit the box. On one side—that from which the wheel acts—a recess is left in the interior to receive and retain oil in considerable quantity, so that the lubrication may be abundant and prevent heating. With every attention to lubrication it is, however, very difficult, when the weight upon the step is great, to prevent its becoming hot, evaporating the oil, and destroying the rubbing surfaces. Various modes of remedying the evil have been attempted; but the best expedient hitherto tried is to enlarge the surface as much as convenient. Formerly, the end of the shaft was greatly reduced to form the foot—often, indeed, a pin was inserted and made to serve the functions of a foot; but at present the foot is formed on the same principle as any other bearing—namely, with as much bearing surface as the diameter will allow. But even this is often found too little, and the next resource is to continue the wheel boss and give the foot a conical form, thereby increasing the supporting surface as much as circumstances will admit.

We have also seen attempts to line the brass step with ribs of steel to increase its durability; but without success. A step made on Babbitt's principle, and lined with soft metal, would, in our opinion, offer a better chance of success than any scheme which has hitherto been attempted. But the experiment remains to be made on a proper scale, and with sufficiently good workmanship, to test the principle thoroughly before its being adopted very extensively in mill-work.

Among the more ingenious of the older contrivances for rendering foot-bearings durable was that of attaching a hardened steel plate to the extremity of the foot by a square *tang*, which was driven hard into a corresponding hole in the foot. On the under side of this disk a groove was cut across, the better to distribute the oil which found its way to the bottom of the step by vertical grooves cut in it.

This was found to work very well when there was little lateral stress upon the shaft; but ultimately gave place to an arrangement which is sometimes adopted in modern work, and which consists in inserting a steel pivot into the lower end of the shaft. When this pivot is bound in its place by a malleable-iron ring put on hot, the arrangement is one of the best which can be adopted; but the original mode of simply boring a hole in the end of the shaft and inserting the pivot, without any further lateral support, left the foot very weak and inadequate to sustain any considerable amount of lateral stress.

Another scheme, also sometimes put in practice in modern work, when the shaft is very large, is to make the foot turn on conical rollers, on the same principle as horizontal shafts are sometimes made to turn on parallel friction rollers to diminish the amount of friction, by converting a rubbing into a rolling motion, with only the sliding action of the small axes which retain the rollers in their places. The cones, however, require very accurate workmanship, and therefore become expensive, and are, moreover, very liable to get out of order; they are, in consequence, very seldom employed. A modification of the conical rollers, consisting of a single ball placed under the foot of the shaft, although very rarely tried in mill-work, seems to offer advantages more than equivalent to the additional workmanship which it would entail, by dividing the motion, in some measure, between the shaft and itself, and leaving an open space to receive oil, which would tend materially to keep the foot cool. This arrangement is almost universally adopted in vertical sugar-mills, and is found to answer, although in process of time the ball does become flattened, and, accordingly, requires to be replaced.

The scheme of the late Mr. Bramah, of supporting the pivot entirely on water, the pressure of which was to be maintained by a small forcing-pump and stop-cock, would, if all tear and wear could be avoided, be perfect; but unfortunately it holds out little prospect of being successfully applied to the end in question, although there appears little doubt that it will ultimately be found both practicable and efficient as applied to railway turn-tables, in which the bearing surface is large, and the only problem to be resolved is the diminution of friction.

Water has been successfully applied to keep the common foot-step cool, by simply perforating the foot-box and running a stream constantly through it. An example of this may be seen at the Deanston mills.

Sizes and proportions of bolts.—The bolts employed in securing together the pedestals and parts of the fixings of shaft-geering constitute another important element in mill-work. Bolts may be generally described as pins having a *head* formed on one end, and the other end screwed externally to enter an internally screwed ring, technically named a *nut*. When the bolt is passed through holes placed oppositely in two pieces, a thin ring or washer being first placed on the screwed end of the bolt, if the nut be then put on and screwed tightly down upon the washer the two pieces will be held firmly together between this last and the head, the *body* of the bolt, or part between, serving as the medium through which the force is maintained by one surface upon that opposite.

Bolts are denominated according to their diameters of the body part, $\frac{1}{2}$-inch, $\frac{5}{8}$-inch, $\frac{3}{4}$-inch, $\frac{7}{8}$-inch, 1-inch, $1\frac{1}{4}$-inch, &c., bolts; the particular diameter being determined in any case by the supposed tension to which the bolt will be exposed. It is rarely that this force can be estimated even approximately; but assuming it to be known, the tension ought not to exceed $1\frac{1}{2}$ ton on the square inch of section. Therefore, if we designate by T the tension in tons, that is, the effort tending to separate the head and nut by tearing the body part of the bolt asunder, and the diameter in inches by D, we have the simple formula,

$$D = \tfrac{3}{4} \sqrt{T}.$$

Thus, supposing the known tension to be nine tons, then,

$$D = \tfrac{3}{4} \sqrt{9} = 2\tfrac{1}{4} \text{ inches},$$

the diameter of the bolt necessary to resist that pressure.

The number of consecutive threads in an inch, that is, the pitch of the screw, is regulated by the diameter of the bolt. For small bolts of about $\frac{1}{2}$-inch the pitch is usually about a sixth of the diameter, but relatively decreases inversely with the increase of diameter.

The following table is that of the dies and taps of an extensive millwright and engineering establishment in Glasgow, and it does not differ sensibly from the numbers adopted in some other works.

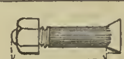
The depth of the thread is also a matter of importance. The section of thread most approved of for strength and easy motion of the nut is an equilateral triangle, thus △, the bevelled sides being equal between themselves and to the base or pitch.

Diameter of screw in inches.	Threads in an inch.	Diameter of screw in inches.	Threads in an inch.
½	12	1¾	5
⅝	11	1⅞	4½
¾	10	2	4½
⅞	8¾	2⅛	4
1	8	2¼	4
1⅛	7½	2⅜	3½
1¼	7	2½	3½
1⅜	6½	2¾	3
1½	6	3	3
1⅝	5½		

Bolts of larger diameter than those named in the annexed table are usually chased in the screw-cutting lathe, and in that case the thread is commonly made of a rectangular section; but such bolts are very rarely required in mill-work, and when they do happen to be employed, it is under such circumstances as remove them from the ordinary class of bolts and the proportions therein recognized.

The length of the body of the bolt must, of course, depend upon circumstances; but a certain proportion is observed between the diameter and the sizes of head and nut. For common bolts the head is usually square, and the nut six-paned, that is, has six facets on its periphery. Sometimes, also, the head has the same form, and occasionally it is made round, and for particular purposes it is conical, but oftener pyramidal. When of this shape, it is intended to be *flush* or *even* with the surface of the piece into which the bolt is inserted, and it is then said to be *countersunk.* The cover-bolts of pedestals are of this form, being necessarily flush with the sole of the pedestal. The thickness of the head when of the usual form is from two-thirds to three-fourths of the diameter of the bolt; and the diameter of its circumscribed circle is double of the primary diameter. The thickness of the nut is usually made sufficient to contain from eight to ten threads, the smaller having proportionally the greater depth. The part of the body towards the head, equal in length to a third of the whole, is usually made square, and the remaining part or two-thirds is round; and of this a portion equal at least to double the thickness of the nut is screwed. Sometimes, however, as in pedestal cover-bolts, the whole length of the body is cylindrical, the bolt being prevented from turning round when the nut is being screwed up by the pyramidal countersunk head.

Although the length of bolts generally can only be assigned for particular cases, those adapted for particular sizes of pedestals may be given. These, it is true, will vary with the particular form of pedestal used; but the sizes given in the following table will be found very generally applicable for those of good proportions.

Diameter of journal.	Diameter of bolts.	 Holding.	 Cover.	 Double-ended.	
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1½	½	3¼	4¼	2¼	5
1¾	⅝	3¼	4¼	2¼	5
2	⅝	3¾	5	2½	6
2¼	¾	4	5½	2^{2}	6½
2½	¾	4	5¾	2¾	6¾
2¾	¾	4¼	6¼	3	7¼
3	⅞	4½	6¾	3	7¾
3¼	⅞	4⅝	7½	3⅛	8¼
3½	⅞	4¾	8	3¼	8¾
3¾	1	4¾	8½	3½	9
4	1	5	9	3¾	9½
4¼	1⅛	5½	9⅝	4	10¼
4½	1¼	6	10¼	4¼	10¾
4¾	1¼	6⅓	10½	4½	11¼
5	1⅜	6¼	11	4¾	11¾
5¼	1⅜	6½	11½	4¾	12¼
5½	1⅜	6⅝	12	5	12½
5¾	1½	6¾	12¾	5¼	13
6	1½	7	13¼	5¼	13¾
6¼	1⅝	7¼	13¾	5½	14½
6½	1⅝	7½	14	5¾	15
6¾	1¾	8¼	14½	6	16
7	1⅞	8¾	15	6¼	16½
7¼	2	8⅞	15¾	6½	17
7½	2	9	16¼	6¾	17¼
7¾	2⅛	9¼	16¾	7	18
8	2⅛	9½	17¼	7¼	18¾
8¼	2¼	9¾	18½	7¾	19½
8½	2½	10	19¾	8	20¼
9	2⅝	10½	20	8¼	21
9½	2¾	11	20¾	8½	22

The heads of bolts intended for wood are commonly segments of a sphere; and the bolt is not often provided with a nut, the holding being in the wood itself. But sometimes, when the wood is thin, the screw is passed sufficiently far through to take a broad wash and nut above it, an arrangement which gives strength in proportion to the acting surface.

Guide pulleys.—It frequently happens, when the power is to be conveyed by a belt, that the connection cannot be obtained directly, in consequence of the relative positions of the shafts, which may be placed obliquely to one another; and sometimes other parts of the geering, machinery, cross-beams of the building, and the like, come between the points to be connected, and by their intervention prevent the belt from passing immediately from one point to the other. Under these circumstances, it is necessary to pass the belt over guide pulleys.

An example of the common guide-pulley frame is given in Figs. 2113 and 2114. The axes of the pulleys are adjustable in the frame B to any required angle within a certain range in a common plane, which is parallel with a plane passing through the driving axis and perpendicular to the plane of the driven shaft. When the belt, therefore, passes from the driver over one of the guide pulleys and is returned upon the other, the bight will be thrown into a plane at right angles to the normal plane, and a pulley placed in that plane, its axis coinciding with it, will be driven by the belt without any tendency to change its plane of action.

We have supposed the beams to be parallel and perpendicular to one another; but the arrangement may be adapted to other positions by placing the guide pulleys in different planes; and in order to allow of further accommodation, the frame may be made adjustable at the point of attachment to the beam at D.

The above treatise on geering has been taken from the Engineer and Machinist's Assistant, and is generally admitted to be the best yet published.

GEODESY, literally signifies the *division of the earth*, in which sense it is synonymous with land surveying; but it is usually employed in a more general sense to denote that part of practical geometry which has for its object the determination of the magnitude and figure either of the whole earth, or of any given portion of its surface. In this sense it comprehends all the geometrical or trigonometrical operations that are necessary for constructing a map of a country, measuring the lengths of degrees, &c. In order to construct an accurate map, or determine the form and dimensions of a country, it is necessary, in the first place, to determine the absolute distances between the several stations or points; secondly, to determine the azimuths of the lines thus measured, that is, their situation with respect to the meridian; and thirdly, the differences of latitude and longitude of the stations. The operations necessary for determining the absolute distances, comprehending the measurement of a base, the observation of angles, the computation of the sides of the triangles, and their reduction to the same level, are called the *geodesical* or *geodetical* operations; while those which are required for determining the azimuths and latitudes are called the *astronomical* operations. The determination of the figure and dimensions of the earth is a problem of very great importance to astronomy and geography, and has accordingly at all times been a subject of much interest to mathematicians; but it is only since towards the middle of the last century that operations on an adequate scale for its solution have been undertaken in different parts of the world.

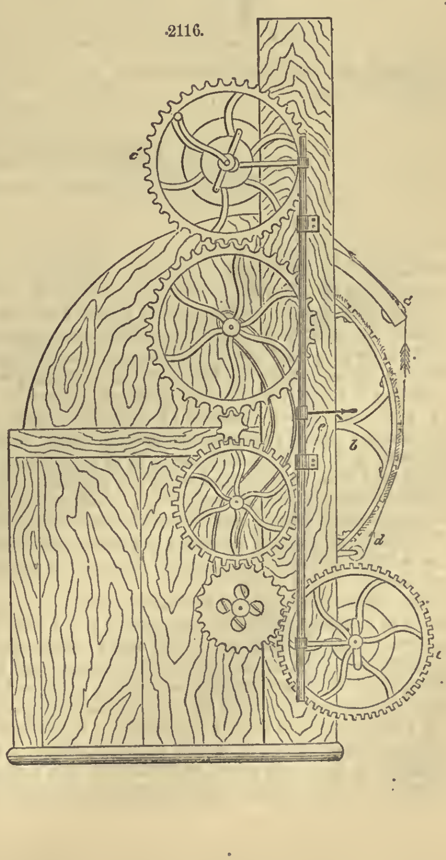
GERMAN SILVER. An alloy composed of copper, nickel, and zinc, in various proportions, according to the purposes for which it is to be used. As a substitute for silver, it should be composed of 25 parts of nickel, 25 of zinc, and 50 of copper. An alloy better adapted for rolling, has a larger proportion of copper, 60 parts, and less of zinc, 20. For castings, as candlesticks, bells, &c., 20 of nickel, 20 of zinc, 60 of copper, and 3 of lead. The analysis of the true German silver from the mines of Hildburghausen, gives of copper 40·4 parts, nickel 31·6, zinc 25·4, iron 2·6 See Metals and Alloys.

GIB AND KEY. The fixed wedge and the driving wedge for tightening the strap which holds the brasses at the end by a connecting-rod in steam machinery. See Engines, Details of.

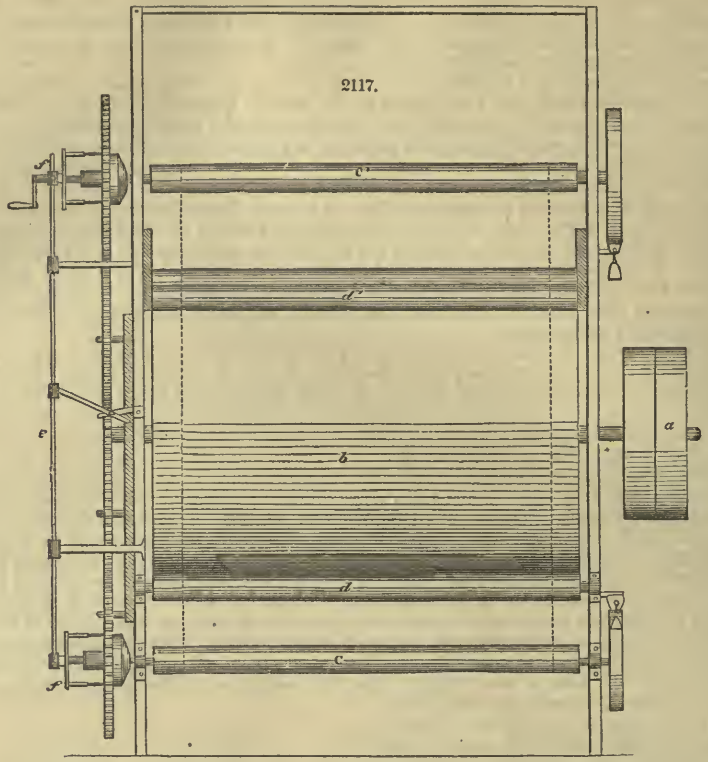
GIG, *for napping cloth* Fig. 2116 is a front elevation of gig.

The cloth to be napped is first wound on the roller c', passed down over the two straining rollers d' d', to the cloth roller c. By means of the shaft e, which is mounted at each end with two slipping clutches $f\,f$, c' is thrown out of geer, and the lower roller c thrown in. The cloth is then drawn down

2116.

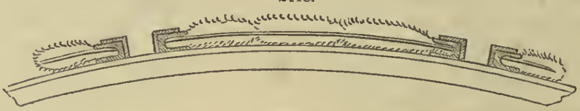


2117.



wards over the revolving drum *b*, which is set with teazles, as seen in Fig. 2118, until the whole length has passed over.

2118.



The action of the two cloth rollers is then reversed, *c'* being thrown into geer, and the cloth passes back again over the teazles, and this is continued until the nap is sufficiently raised. The straining roller *d'* may be adjusted to give more or less strain on the cloth at will.

GILDING is the covering, with a plate or film of gold, metallic or other surfaces. The application is either for *utility*, as where it prevents the oxidation of drinking or other vessels for domestic use, of watch-springs, and the steeled parts of small machinery; or for *ornament*, as in picture and japan frames. Its use under the former of these aspects is daily extending.

Gilding is effected by several different processes.

1. By means of an *amalgam* of gold and mercury, which is best made by heating pure mercury in a black-lead crucible to near the boiling point, and adding one-sixth or one-seventh in weight of fine gold in very thin plates, first brought to a red-heat. The mixture is then stirred, until the gold is dissolved and well incorporated with the quicksilver. When cooled, the resulting mass is subjected to gentle pressure in soft porous leather, which separates the excess of mercury; and there remains in the skin a yellowish silvery-looking substance, which is the amalgam.

In gilding silver, this amalgam is rubbed over the surface, which is first well cleaned, and the mercury is then driven off, by exposing the article operated on to a clear charcoal fire. It is then to be burnished.

The surface of copper and brass, after being cleaned, may be rubbed over with a solution of protonitrate of mercury, which is decomposed, and leaves a thin pellicle of metallic mercury to amalgamate upon the surface. This insures the union of the gold amalgam, which is then rubbed on, heated and burnished, as before. In this mode surfaces may be completely coated with an exceedingly small proportion of gold, as is shown in the case of brass buttons, of which 144 may be covered on both sides with the consumption of not more than five grains of gold.

In gilding iron and steel with amalgam, a solution of mercury in nitrous acid is previously applied A deposit takes place of mercury in close contact with the surface, even if it does not appreciably amalgamate with the iron. It facilitates the adhesion of the gold amalgam, which is applied and treated as before. This method for iron and steel cannot be recommended; for the nitrous acid

liberated attacks the surface, and impairs its polish; and the heat, besides, necessary for driving off the mercury, injures the temper of the metal. Cutting instruments, therefore, or any that require to be tempered, should not be gilded in this manner. The application of gold leaf to such instruments for the same end is similarly objectionable for the same reasons.

Another process for iron and steel consists in applying a solution of sulphate of copper previous to rubbing on the gold amalgam or laying on the gold leaf. This is as exceptionable, and for similar reasons, as the former method.

2. Better than either of the last-mentioned, at least for iron and steel, is the process with *etherealized gold.* In this a solution of gold is made in nitro-muriatic acid, and there is added to it twice as much sulphuric ether. The mixture must be shaken, and then allowed to repose, when the ether with the chloride of gold will separate from the remaining liquid, and rest above it. This dark-colored ethereal solution is poured off from the light-colored liquid beneath, and can be preserved for use in tight bottles, excluded from light. When applied, it is with a very fine brush, or camel's hair pencil; the ether evaporates immediately, leaving a coating of gold. This is burnished after being heated. The adhesion is more perfect, however, if the article be raised to a temperature approaching redness.

3. A mode of gilding silver is sometimes practised, which consists in reducing to ashes linen rags that have been previously dipped in a solution of chloride of gold, and rubbing them on the surface to be gilt with a piece of leather, cork, or with the finger. The fine particles of gold will thus adhere to the silver. The article is then washed to receive the adhering ashes, and burnished. This is a simple and easy method, and consumes but little gold.

Brass or copper may be readily gilt, by being dipped in a dilute *neutral* solution of chloride of gold, and then washed and burnished.

For the preparation of the chloride of gold, see GOLD.

4. A process analogous to this last was patented in 1836 by Elkington, an English gilt toy-maker, and is well adapted for small articles. It consists in immersing them in a hot solution of chloride of gold, to which has been added a considerable excess of bicarbonate of potash.

5. By far the neatest and most unobjectionable among the chemical methods of gilding is the galvanic process, proposed first in 1840 by De la Rive. Since then it has received, in the hands of various persons, modifications facilitating and extending its application. For these and other details, see ELECTRO-METALLURGY.

Gilding is also effected:

6. Mechanically, by covering with gold-leaf, which comprehends a very extensive range of application. Thus, the principal metals may be gilt; thus, several natural or artificial earths, such as marble, plates, and porcelain, objects in glass, leather, paper or pasteboard, and wood, may be made to assume entirely, or in part, the appearance and some of the physical advantages of gold.

For work intended to be out of doors, or exposed to the weather, a sizing is first applied, made of boiled linseed-oil and red ochre. On this the gold-leaf is laid. This is the *oil-gilding* of the older treatises. In gilding *glass* or *porcelain,* powdered gold is mixed to a proper consistence with a solution of borax in water, and applied with a soft brush or pencil. The articles are then heated in an oven to a temperature sufficient to burn off the gum and vitrify the borax, whereby the gold is cemented to the surface. Then it must be well burnished. The general method of using gold in *powder* (for the various preparation of which, see GOLD) was known and described in the earlier treatises as *gold japanning.* But in the true japanning, the gold was protected by a varnish, and not burnished.

Leather is gilt by dusting the surface with powdered mastic, upon which the gold-leaf is applied and burnished. The *lettering* and other emblems on bound books is generally done without sizing, by applying the gold-leaf to the leather, and imprinting with the stamps or types moderately warm. In lettering on muslin, mastic or isinglass is better to be applied.

Paper, or parchment, is gilt by applying a thin coat of gum, or size, laying on the gold-leaf before the coat is perfectly dry, and burnishing, as before. The edges of books are best gilt by applying to them in the press a thin size of one part powdered rock-candy and four parts Armenian bole, mixed with the white of egg; then the gold-leaf is put on and burnished.

Articles in wood, such as picture and mirror frames, are best treated with a sizing prepared from clippings of vellum or parchment, boiled in water to a stiff jelly, and mixed with Paris white, plaster of Paris, or yellow ochre.

For *gold inks,* permanent and sympathetic, see INK.

False gilding, is the application, for cheapness, of other substances than pure gold, in which, however, the appearance of that metal is more or less imitated. For this purpose is used Dutch leaf, (which is copper gilt, and then beaten out,) and silver, and tinfoil. The Dutch leaf has the appearance, at first, of true gold, which may be secured and continued by a coat of transparent varnish. Silver and tinfoil assume the appearance of gold by means of a varnish or lacker composed of aloes, gum-sandarac, and white resin, (the resin being about as much as the other two ingredients, whose propositions are nearly equal,) which are boiled in their own weight of linseed-oil. When well boiled to a syrup, about a half per cent. of red-lead is added, and the liquor strained through a flannel bag. This was the method formerly used for the leather hangings of apartments, beautiful specimens of which are still seen in Europe. These hangings have long gone out of vogue, but will probably be recalled.

For what concerns the details of the art of gilding, the precautions to be taken in the several processes, the apparatus and implements employed by the practical workman, and the method of producing different characteristics in the work—*frosting, deading,* &c., &c.—reference must be had to larger treatises and manuals; among which may be mentioned chiefly, D'Arcet: Mémoire sur l'Art de Dorer Paris. 1818.

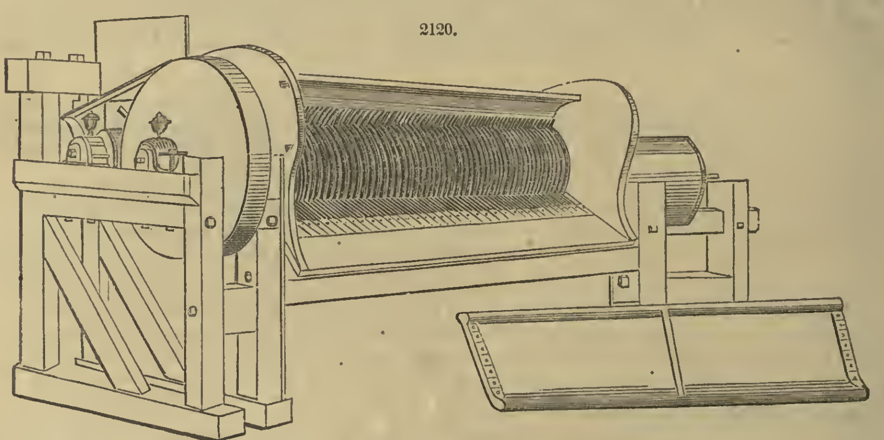
That the ancients practised this art, though in a more expensive manner than we do, is apparent from the Egyptian and Etruscan remains, which date back three thousand years, and more. Pliny the Elder has left fine details of its state in the first century of our era. As well as can be made out in

the uncertainty of weights and measures, the thinnest gold-leaf then was about twenty-two times thicker than what can be made now. The methods were the same in principle as our own. Marble, and articles that would not bear heat, were coated with white of egg; wood, with divers kind of glue; all generally termed *leucophoron*. Metals were gilded with native or prepared quicksilver (hydrargyrum), and the various washes of salt, vinegar, and alum are also mentioned. (Plin. Hist. Nat. xxxiii. 20.) The relics of Herculaneum, for instance, show that the success of these ancient processes, whether due to labor or otherwise, is far more than proportionate to what might be expected from our superiority in theoretical science.

GIMBALS, or GIMBOLS. A piece of mechanism consisting of two brass hoops or rings which move within one another, each perpendicularly to its plane, about two axes placed at right angles to each other. A body suspended in this manner, having a free motion in two directions at right angles, will assume the vertical position: hence the apparatus is employed for suspending portable or mountain barometers, sea-compasses, &c.

GIN. This term is applied in mechanics to various and widely differing machines, to engines for raising great weights, driving piles, &c., as well as those employed in cleansing of cotton and wool, and its preparation for the market or for carding. The most simple, as well as the most ancient, cotton-gin is the roller gin, which consists of fluted rollers about five-eighths of an inch in diameter, and from nine to sixteen inches long, placed parallelly in a frame, which keeps them almost in contact. The rollers revolve in opposite directions: the cotton is drawn through between the rollers, whilst the seeds are prevented from passing from the narrowness of the space. This machine is still used for the finer and longer stapled cottons; but the operation is tedious and expensive; and the saw-gin, invented by Eli Whitney, in 1793, from its general use, and its wondrous effects on the extension of cotton cultivation, and influence on manufactures and commerce, may now claim distinction and consideration almost exclusively as the cotton-gin. In its main features this machine still continues as first invented by Whitney; but in various details and workmanship, it has been the subject of many improvements. Fig. 2120 represents a perspective view of a cotton-gin, constructed by Bates, Hyde & Co., of the Eagle

2120.



Cotton-Gin Manufactory, Bridgewater, Mass., who are the owners of several patented improvements on the machine, and from whom we take the following drawings and descriptions. Fig. 2121 is a section of the gin.

The frame of the machine is made either of wood or iron, usually of wood, with tenons and mortises, and screwed together firmly with joint-bolts. The sides are ceiled with boards inside the timber, and the top ceiling above the brush is made in one piece, so as to be readily removed.

The grate-fall, or breast, into which the seed cotton is thrown, is formed with ends, or heads, of cast-iron, and pear-shaped; the lower and back side being composed of cast-iron grates, screwed firmly to the wood-work of the breast; the saws projecting through the interstices between the grates, from one to two inches; the upper and back part of the grate-fall, called the "hollow," is hung upon hinges, and may be raised or lowered at pleasure, and fastened in any desired position by joint-bolts through the grate-fall heads.

The seed-board makes the front part of the breast, and stands nearly perpendicular, leaving a space between it and the grates for the discharge of the seed; it is hung upon pivots at the top at each end, so that the bottom may be swung outward and the hopper emptied at any time. When in place, the bottom is fastened by small slide-bolts. The position and angle of the seed-board may be readily varied and adjusted, by altering the position of the slides upon which the pivots rest. These slides are fixed to the grate-fall heads by small bolts passing through slots, having a nut outside.

The grate-fall, or breast, is hung to the front top timber of the frame, by stout hinges above the saw-cylinder, and the lower part rests upon two short screws in the front piece. That part of the hinge, or butt, which is attached to the top timber is so fixed as to slide up or down by means of slots and an adjusting screw, and is fastened in the desired position by bolt-nuts.

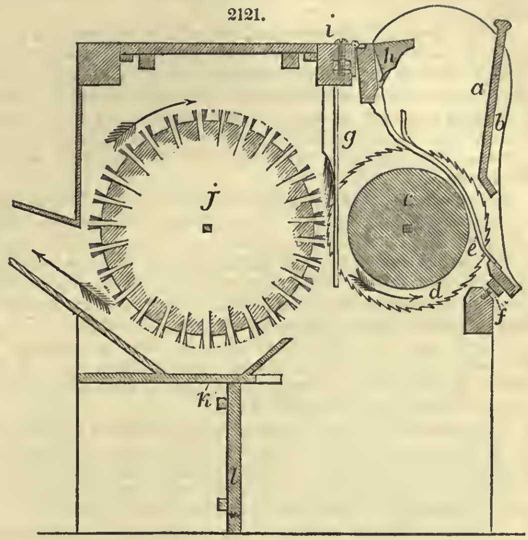
The saw-cylinder is made of wooden staves, about two inches thick, upon an iron shaft, and turned in a lathe of a uniform diameter; and, by the application of a small saw, when in the lathe, grooves

are formed to receive the saw-segments, which are made of the best cast-steel, and inserted and fastened into these grooves.

There is a set of wooden grates behind the saw-cylinder, and a row of hair, or bristles, called the "moter," to separate the false seeds, motes, and dirt from the ginned cotton.

The brush is made of about twenty inches diameter, cylindrical, having slits lengthwise between

2121.



a, Grate-fall head, or end of breast.
b, Seed-board.
c, Saw-cylinder.
d, Saw.
e, "Patent detached grate."
f, Screw or bolt on which the grate-fall rests.
g, Back board, to which are attached the back grates and "patent moter."
h, Grate-fall hollow, which is hung upon hinges, and may be raised or lowered at pleasure.
i, Sliding-butt, by means of which the saw-tooth may be made to assume any desired angle with the curved surface or front of the grate.
j, "Patent brush."
k, Sliding mote-board.
l, Bottom board.

the rows of bristles, and a hole around the shaft to receive the air as the brush revolves; and a rapid centrifugal motion is given to the air, which is forced out with great power between the rows of bristles.

Behind the brush is an opening, the length of the frame, into the lint-room, and beneath the brush a sliding-board, called the mote-board, which may be slid back or forward for the purpose of regulating the draft of the gin, and properly separating the motes, dirt, and leaf from the clean cotton.

In the saw-gin, as ordinarily constructed, the cotton is liable to collect in the spaces or interstices between the grates, and around them above the saws, thus choking or clogging the grate, and preventing the rising and free escape of the roll of seed-cotton. The patent detached grate, instead of being attached directly to the wood part of the breast at the top, has an arm or brace extending out behind, through which it is screwed to the wood, so that the top of the grate stands out and is detached from the wood, and has a space behind of a quarter inch, or more, between it and the wood, and also a space between it and the adjacent grates; so that there is no chance for the cotton to collect above the saws, and the choking is entirely avoided.

Many efforts have been made so to improve the saw-gin, as to separate from the fibres of cotton motes and other impurities. By some this has been essayed by means of rotating brushes acting on the fibres, and carrying them from the grate to the stripping-brush, rotating in a reverse direction to the saws. Some have used stationary brushes, through which the saws carry the fibres to be stripped of motes and other impurities. The objection to these is, that they act on the cotton only when upon the teeth of the saws, and therefore, instead of separating the motes and other impurities from the fibres to which they adhere, sometimes with considerable tenacity, the fibres are drawn out with the motes, thus occasioning considerable loss of cotton. The object of the moter is to avoid this loss, and to hold on to the motes or other impurities, as the fibres are stripped from the saws by the stripping-brush, the fibres being under the operation of both brushes at the same time. The moter also more effectually stops the current of air generated by the rotation of the stripping-brush from acting on the fibres before they are cleaned, than if located at a greater distance from the point of action of the stripping brush.

GLASS.—The varieties of glass are usually classified according to their technical uses, as follows:

A. *Bottle-glass*, which comprises all glass worked into the form of vessels, &c. It is subdivided, according to the purity of the metal of which it is composed, into

Ordinary bottle-glass, consisting of silica 60, potash or soda 3·1, lime 22·3, alumina 8, and oxide of iron 4.

Glass used for medicinal bottles, composed of silica 71·6, soda 10·6, lime 10, alumina 3, and a very little protoxide of iron.

White bottle-glass, for bottles, tumblers, tubes; containing silica 71·7, soda or potash 15, and lime 10.

B. *Window-glass*, composed of silica 70, potash or soda 15·2, lime 13·3, and alumina 1·82.

C. *Plate-glass*, composed of silica 72, soda or potash 17, lime 6·4, and alumina 2·6. This variety only differs from the preceding by the greater purity and freedom from color of the materials.

D. *Flint-glass*, used for grinding, &c., composed of silica, potash, and oxide of lead.

E. *Crystal*, for optical purposes, composed of silica 59·2, or boracic acid, potash 9, and lead 28.

F. *Strass*. The mass composing the imitations of precious stones, consisting of silica 44, potash 12, with the largest amount of oxide of lead 43, and colored by various metallic oxides. The pigments

used by artists in glass and porcelain, are also included under this head; they are easily fusible glass fluxes, consisting of lead and boracic acid, which can be colored in any manner that is required.

G. *Enamel*, composed of silica, soda, and oxide of lead, but rendered opaque by oxide of tin or antimony. These proportions are not adhered to strictly, but vary greatly in different specimens.

Some of these varieties of glass are in themselves colored, as the dark-brown or green bottle-glass; the light-green bottle-glass, used by chemists; all the varieties mentioned can, however, be colored artificially.

Of the material for glass-making.—In so extensive a branch of manufacture as that of glass, it is quite impossible to prepare or obtain the ingredients in a state of chemical purity previous to fusing them together; certain crude products of art and nature are therefore used, in which the ingredients are contained in some suitable form of combination, and it is left to the process of melting to eject the impurities in a more or less complete manner. In order to understand the nature of this process, and the recipes for mixing the ingredients of the different varieties of glass, it is necessary previously to become acquainted with the crude products which are used in the glass-house for affording silica and the bases.

Silicic acid.—Silica is very abundant in nature, but is seldom sufficiently pure for the manufacture of the finest colorless glass. *Rock crystal* is frequently used for those glasses which are employed as pigments by glass painters. Heated to redness and thrown into water, the state of aggregation of this substance is so changed, that it can easily be reduced to powder. Massive *quartz and flint* are treated in the same manner. *Sand*, however, is the most general and economical source of silica, and renders the process of grinding unnecessary. The great variations in the purity of this material, render a careful selection necessary for the different kinds of glass.

Potash and soda.—The alkali used in the manufacture of ordinary colored glass, (*e. g.* bottle-glass,) is obtained, as far as the potash is concerned, from common *ashes*, and the soda from the *ashes of sea-plants*, or refuse soda. Better kinds of glass are made with *crude potashes and soda-ash*, and the best from *purified* potashes and soda-ash.

Lime.—Every kind of limestone is applicable to the manufacture of glass that is not too poor after being burnt and slaked. When a glass mixture contains more lime than the silica which it comprises is capable of saturating, the excess attacks the material of the crucible, and extracts silica from it; the crucibles are thus quickly eaten away and rendered useless. It is consequently not advisable to employ more than 20 parts of lime for 100 parts of sand.

Lead.—Lead-glass is fused from a mixture containing *litharge* or *minium*, (red-lead.) The latter substance is preferred, on account of its finer state of division.

Discolorizing matters.—White glass seldom or never turns out quite colorless by itself, even when proper proportions and the purest materials for the mixture have been employed in its production. There are always two antagonistic elements to contend with, *carbon*, or carbonaceous matters, and *iron*, which have to be overcome by the so-called discolorizing material. Peroxide of manganese, arsenic, and saltpetre, belong to this class of substances. In all cases the color is removed by oxidation.

Broken glass, or cullet.—Fragments of old glass require particular notice as an indispensable addition to the ingredient of the crucible. The waste glass in the glass-house, and that collected in the neighborhood, is carefully sorted, cleaned, ground, and incorporated with the mixture for similar kinds of glass. These fragments exert a very beneficial action—in addition to the advantage derived from their being reconverted into glass vessels—by inciting fusion and by aiding the union of the bases with the silicic acid.

Of the fuel.—The furnaces employed in glass-houses are intended not only to combine chemically the ingredients of the glass mixture at a glowing heat, but also serve to retain the glass after fusion in a proper state of fluidity for working.

Again, the reheating of the different vessels during working, which is always effected in the glass-furnace, requires imperatively a *flame fire*. That kind of fuel will naturally have the preference which produces the most intensely hot flame, and causes the least amount of damage to the glass and to the sides of the furnace from the deposition of ash. In Germany, *wood* is generally employed, and in some few places *peat*; in England and France, *coal*; in this country, both wood and coal. The best air-dried wood would fall far short of producing the desired effect, in consequence of the water which it contains, (from 15 to 20 per cent.) In has been the practice to bake the air-dried wood in a furnace until the whole of its water has been volatilized. Even this precaution is not perfectly effectual unless soft woods are selected containing a large proportion of hydrogen; and these are cleft into very small billets. Finely cleft wood burns more rapidly and without smoke by coming into more extensive contact with air, it evolves its heat in less time, and although a greater amount of heat is not produced by its means, that heat which is produced, is more intense.

The furnaces.—The construction of the melting furnaces in a glass-house is attended with many difficulties, against which it is almost impossible to provide; and the wear and tear becomes a serious item to the manufacturer.

The furnace is erected over a large flue, or *cave* as it is technically termed, very strongly constructed, and 5 or 6 feet high. On each side of the grate-room, in which the flue terminates, a bank is raised, termed the siege, on which the pots are placed, so that the fire lies, as it were, below the bottom of the pots, and in the centre of the furnace, but stretching through its whole length. The sides of the furnace are a little higher than the top of the pot, and the arch, or crown, is made as low as possible, to be consistent with durability. Openings are made in the sides of the furnace, opposite to each pot, and above all, a high cone is erected for the purpose of draught. In all kinds of glass, except flint, these openings are the only exit for the flames or heat into the cone, and the heat striking directly against the roof or arch of the furnace, is reverberated down upon the pots, finally escaping through these openings or "working holes." This necessitates a great loss of heat, which is obviated in some degree in the flint-glass furnace, where the exit is by means of a flue or chimney, the entrance into which is

low down in the side of the furnace, so that the heat is compelled to encircle the whole pot before it can escape.

The sides of the furnace are constructed of bricks, formed in moulds made for the purpose. The best fire-clay, mixed with the remains of old pots coarsely ground, is the material employed for making these bricks. No cement is employed in the arch of the roof; the expansion of the stone, and the partial fusing of the interior surfaces afterwards, binds the whole sufficiently well together.

The pots.—These crucibles, or pots, are next in importance to the furnaces, and every care is taken in their production. The best fire-clay, mixed with varying proportions of the remains of the old pots, is employed, and the *tempering*, or previous preparation of the mixture, requires great attention.

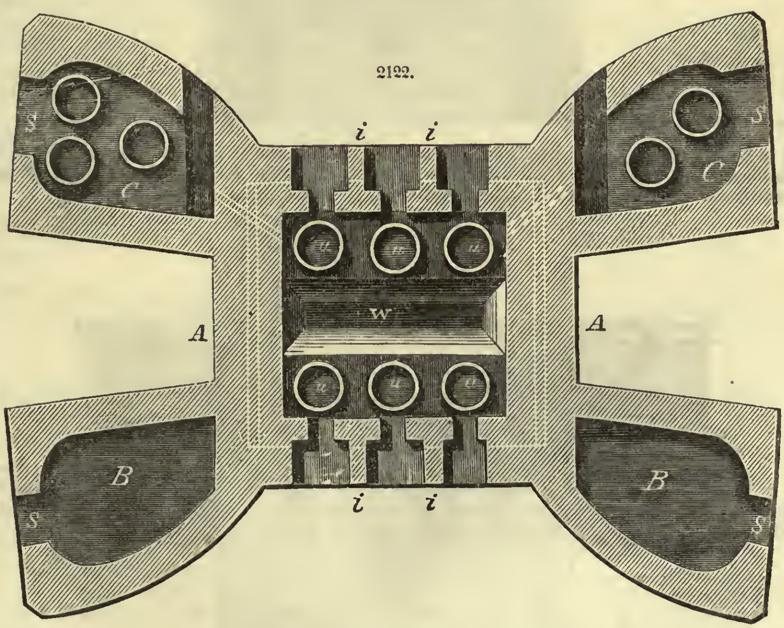
By means of levers worked through different openings of the furnaces, the pot is brought into its proper position, and is then "glazed," as it is technically termed, before being filled with materials; *i. e.* some old glass is thrown into it, and spread over the sides in the melted state; this then penetrates to the depth of a few lines, into the substance of the pot, and forms a hard, difficultly fusible glass, which protects the pot from the further action of the materials.

Preparation of the materials.—It has already been stated that a great saving of fuel and time is effected by intimately mixing the materials in the most minute state of division. The materials are either mixed together in heaps, or, better, in the slowly revolving barrels similar to those employed in the powder-mills.

Melting.—When the melting point is attained, the simply calcined or fritted mixture is introduced but not all at once. The mass of glass which a pot will hold, occupies before fusion, in the state of a mixture, twice the space of the melted glass. One-third of the mixture is first introduced through the working-holes, by means of shovels, and the other two-thirds are added successively, when the previous portion appears thoroughly melted.

During the whole period of the melting, the stokers keep the furnace well supplied with fuel, so as to prevent any portion of the grates becoming uncovered, since a rush of cold air from below would probably split some of the pots from top to bottom. During this operation, the founders are engaged in observing the progress of the fusion, by taking from time to time proofs, or drops, from the pots, by means of a short rod, flattened at one end, and examining whether any undissolved grains of sand are perceptible on cooling, and whether the mass, which still contains a quantity of air-bubbles, appears uniform throughout. At the close of the melting process, the contents of the pot are not by any means pure, or equally mixed. The solid matter is indeed all dissolved, but the mass of glass is full of small bubbles of gas, presents a spongy rather than a dense appearance, and is not yet in a state fit for working. The surface is also covered by a layer of so-called *glass-gall.*

2122.



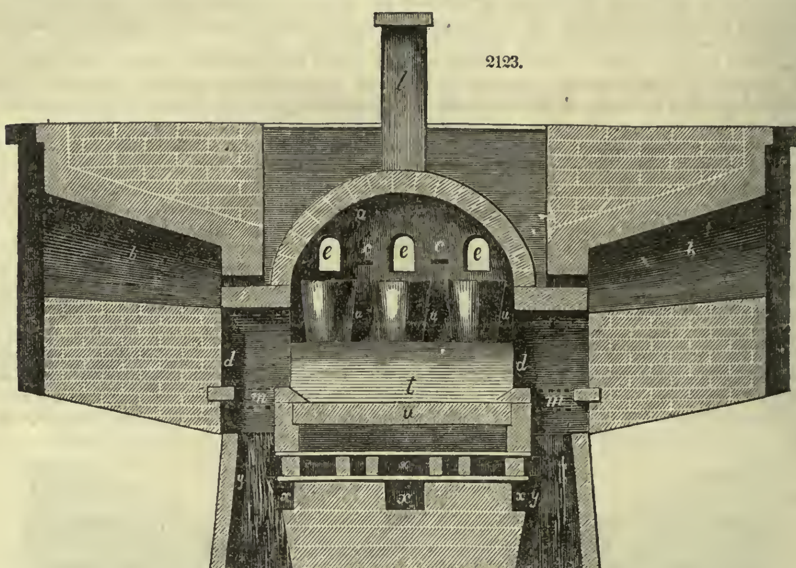
Fining.—The last part of the process of glass-making is now arrived, which is termed *the fining*, and the object of this is the removal of the air-bubbles and impurities, such as undissolved grains of sand, &c., from the chemically finished glass, in order to prepare it for working. This process is a simple separation of the heterogeneous substances by subsidence, in which the heavier particles settle down to the bottom, and the gas-bubbles rise and disperse on the surface of the melted mass. During this time, which always comprises several hours, no chemical change occurs, with the exception of the volatilization of a little alkali; but the proofs drawn by the founder are much more uniform in texture and freer from bubbles, until, at length, the whole is recognized as thoroughly fined. The mass of glass which is now ready, can only be formed into vessels when it possesses a certain state of consistency.

and this is entirely dependent upon a fixed temperature which has been very much exceeded during this period. The working, consequently, does not immediately follow the fining process, but a period intervenes, during which the heat of the furnace is allowed to sink to that temperature at which the glass is in the best condition for working or blowing. Observations with Wedgwood's Pyrometer have shown the proper temperature for working to be 70°.

Bottle-glass.—All kinds of hollow articles, as bottles, drinking vessels, preserving glasses, chimney glasses for lamps, goblets, tubes, and chemical vessels in general, from the finest Bohemian glass for cutting and grinding, to the ordinary green bottle-glass, are included under this head.

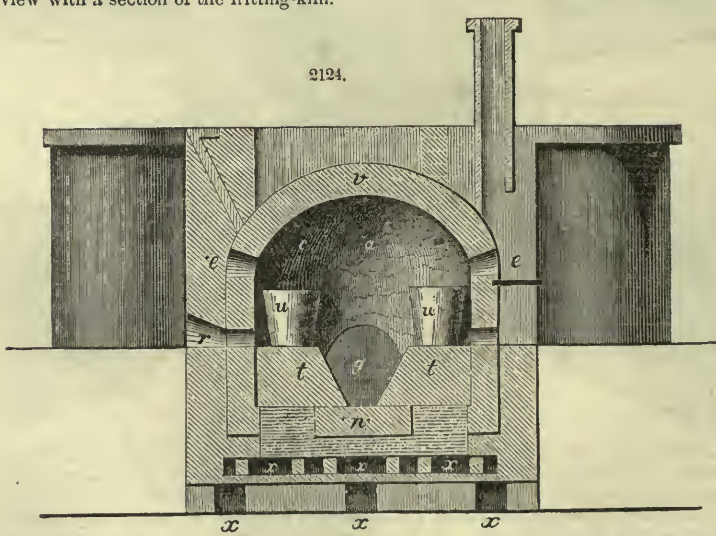
Glass furnace.—The arrangement of an ordinary glass furnace is shown in Figs. 2122, 2123, 2124 and 2125. The figures represent a four-sided furnace, intended for six glass-pots, and when constructed in an appropriate manner, can be used for all kinds of glass belonging to this class. Fig. 2122 rep-

2123.



resents a horizontal section at the height of the sieges or seats. Fig. 2123 a perpendicular section through the teazing-arch. Fig. 2124 is also a perpendicular section through the sieges, and Fig. 2125 is a front view with a section of the fritting-kiln.

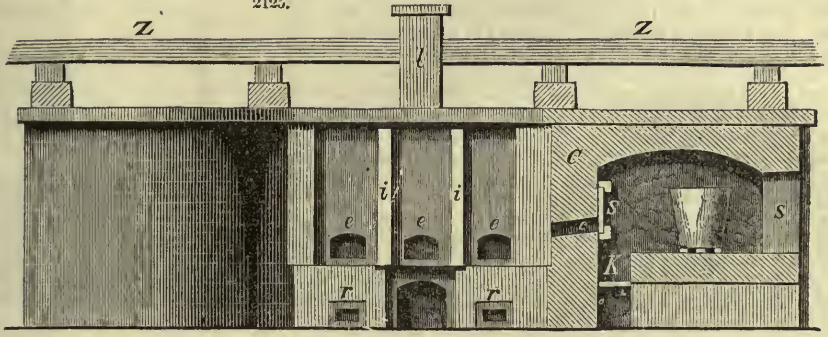
2124.



There are four side-kilns connected with the main furnace A, in the shape of four wings, viz. two cooling or annealing furnaces B B, and two fritting-kilns C C. Above the foundation, in which the drains $x\,x\,x$ are excavated, the sole-stone w is placed, which forms the bottom of the fire-room. The two fire-places and grates $m\,m$ are situated above the ash-pits y, and are exactly opposite to each other;

they are supplied with fuel from the arches *b b* and *d d*, whilst the flames from the two extremities meet in the fire-room *g*, Fig. 2124, and enter together the space *a a* occupied by the pots *u u u u*, and—reverberating from the four-sided arch—escape at last through the flues *c c*, eight inches in width, into the side ovens, of which two *c c* can be heated by separate fires *k k*; the damper S′, Fig. 2125, shuts off the flame from the furnace A when required. The uprights *i i i i* separate the working spaces of the glass-blowers, who obtain access to the glass in the pots through the working-holes *e e e*. Immediately below these are the openings *r r r*, which can be opened for removing the pots, when broken or worn out, from the sieges, to which they often adhere. In order to retain the heat in the furnace, the

2125.



working-holes are made as narrow as possible, and consequently much smaller than the pots; when it is necessary to change the latter, they are removed through the side arches, of which there are two in every furnace, and these are kept constantly bricked up, except when actually in use. Chimneys *l* are sometimes erected over one or more of the working-holes to carry off the heat and the vapors from the pots; these, however, are not essential, and are not often used. The side-kilns are accessible by the doors S S S. Wood is placed on the scaffolding *z z* to dry. The cupola or arch *v* is walled over with ordinary bricks, and the corners are filled with sand and earth.

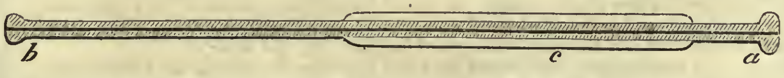
The round melting-furnaces, although very commonly used, are not so commodious as those of quadrangular form under the same circumstances.

Bottle-glass.—Composition.—In choosing ingredients for this kind of glass, economy is the chief object; color and appearance are here of no moment. The following examples are calculated for 100 lbs. of sand.

For Champagne bottles according to Jahkel.	Ordinary green bottle-glass.	English bottle-glass.
200 lbs. felspar.	72 lbs. of lime.	100 lbs. lixiviated ashes.
20 " lime.	280—278 " lixiviated wood-ashes.	40— 90 " kelp.
15 " common salt.		30— 40 " wood-ashes.
125 " iron slag.		80—100 " clay.
		100 " cullet.

Mechanical operations.—The manufacture of bottles affords a good instance of the dexterous manipulations which are practised in blowing glass. The most important instrument is the "*pipe*," Fig. 2126.

2126.



This is a tube composed of wrought-iron, 4 to 5 feet long, 1 inch thick, and about ½ inch in the bore, having a knob at each end, the one of which *a* serves as a mouth-piece, whilst to the other *b* the melted glass is attached. To protect the workmen from the heat of the metal, a wooden handle *c*, about a foot in length, surrounds the upper part. As soon as the working-holes are opened the workman attaches as much melted glass to the end of the pipe *b* as he considers necessary for the production of a single bottle. By dipping the previously warmed pipe into the pot, a little glass remains attached to *b*; after turning this in the air before the hole, until it is cooled, and blowing slightly into it to render it hollow, a fresh layer of glass may be attached to it in the pot; to this, a third is added in the same manner until the ball at the end of the pipe has accumulated to a sufficient size. That this ball may become uniformly tractable in the subsequent forming, it is held by the workman in the flame of the furnace through the working-hole; it is then brought into one of the round concavities of the *marver*, (constructed at different times from a stone, marble or cast-iron plate,) where the ball gradually assumes the form of a pear-shaped vessel, Fig. 2127. It acquires this shape by the constant rotary motion given by the workman to the pipe whilst the cooling and stiffening of the mass is rendered uniform by the marver, and is prevented shrinking together by constantly blowing into the pipe with very little force. The mass of metal (metal is the technical term applied to glass during working) must be equably distributed round the axis of the pipe, and advanced in front of its mouth, being connected with it only by a short neck.

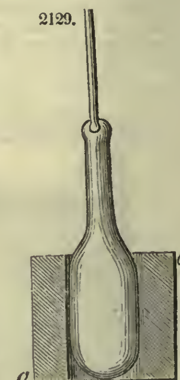
Thus far advanced, the glass has again become cool and is rewarmed by insertion into the working-hole, in such a manner that the front part receives the chief portion of the heat and becomes the

softer. The pear-shaped vessel is now lengthened by the blower, and its form is approached to that of a bottle by a threefold operation; by blowing into the tube with greater force, by *swinging* (backwards and forwards, in the manner of a pendulum) and by a simultaneous constant rotary motion of the pipe round its axis. The globular form which the glass tends to assume under the influence of the blowing, is converted into a long thin egg-shape by the swinging motion, Fig. 2128. The rotation round the axis of the pipe is an essential part of every operation in glass-blowing. The glowing mass of glass creates a powerful current of air in an upward direction, and the lower portion becomes cooled in consequence much more than the upper. This naturally creates an inequality in the resistance offered to the blowing; and the upper portion would be more expanded than the lower if the cooling influence were not allowed to act upon all parts of the surface alike by the revolving motion of the pipe, and this is particularly the case when the pipe has to be held in a horizontal position. The mould *a* (a simple cylindrical hollow block of wood or iron) is placed at the side of the workman who is blowing the pear-shaped vessel; into this he inserts the vessel as soon as it has acquired the proper thickness, in the manner represented at Fig. 2129, and by blowing forcibly into the tube, he presses the glass firmly against the sides of the mould, whilst, by a kind of jerking motion, the neck is drawn out to the proper length. The unfinished bottle is again warmed in the working-hole in such a manner that the lower part only is heated, whilst the other parts remain comparatively cool. In the mean time, another workman or a boy has attached a small quantity of glass to another pipe or rod of iron, called the *punty*, which is also kept hot in the working-hole. Both workmen now stand opposite to each other; and whilst the pipes are kept constantly turning, the punty is forcibly pressed against the middle of the lower part of the bottle which is thus forced inwards, and an even edge is produced, upon which the bottle may stand steadily. The bottle remains for some moments between the two instruments, Fig. 2130, until, by the application of cold iron or a drop of water, the neck can be separated from the pipe. This sudden separation is an operation of constant recurrence in the glass-house, and is effected by a sudden change of temperature produced at the point of separation in the hardened glass, either by the cold application of a drop of water, or by the powerful heat of a red-hot iron or thread of liquid glass from the pot. The point of separation must often be reheated in order to fly on the application of cold water. The bottle is now supported by the punty, as shown at *a*, Fig. 2130, so that the neck can be warmed, and the sharp edges melted round without softening the other parts. A rotating motion is now given to the red-hot neck, the pipe being rolled backwards and forwards upon the knees of the workman. The rim for strengthening the neck is formed from a drop of glass taken from the pot by the edge of the flask and wrapped round the mouth in the form of a thick thread. The bottle, which is now finished, Fig. 2131, is immediately carried by the punty-rod to the annealing-oven by a boy, pushed into its proper place, and the punty-rod is lastly detached from the bottom of the bottle by a sudden sharp jerk. The place where the punty was attached is perceptible in every bottle blown in this manner by the sharp edges where the fracture occurred.

2127.

2128.

2129.



2130.

2131.

Large round bottles are blown without the use of a mould, and when of very large size, like the carboys for sulphuric acid, the aid of steam is called in, by spirting a mouthful of water into the interior, and holding the mouth of the pipe with the thumb.

Attempts have consequently been made by many inventors to furnish the bottle-maker with a mould of such construction as would enable him to secure the formation of a bottle, perfect both as regards form and capacity, at one single operation, without reliance upon his own correctness of sight. The use of moulds of this description, like that of Rickets, which is easily managed, affords a great saving of time, and renders the repeated heating of the bottles unnecessary.

The mould consists of a body which forms the belly of the bottle and of four other parts, a fixed bottom-piece with a movable piston for forming the concavity, and two movable pieces for the neck. Two treadles set these different parts in motion. As soon as the workman has introduced the hollow lengthened globe into the belly of the mould, by pressing with his foot upon the first treadle, he brings up the neck-piece, then forces the glass into contact with all parts of the mould by a powerful blast, and finishes the bottle by working the second treadle which forces the pestle against the bottom. On the removal of the pipe, the rim of the neck is all that remains to be perfected.

Champagne bottles require to be made more than usually strong in consequence of the pressure exerted by the carbonic acid enclosed within them, and they are particularly liable to fracture during the bottle-fermentation of the wine. Yet they will often withstand a pressure of 40 atmospheres, and upwards, (= 600 lbs. on the square inch.)

Crown-glass.—The purest and most beautiful glass is the white "*crown-glass*," manufactured in the Bohemian glass-houses for grinding and polishing. Intended for articles of luxury and art more than for the supply of the ordinary wants of life, the purity and absence of color in the mass is naturally

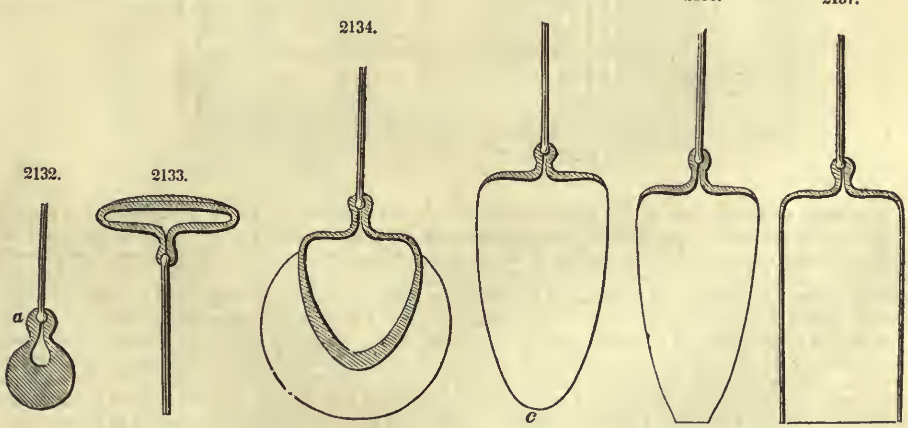
heightened by the grinding and polishing, and is combined with an elegance of form which would be thrown away upon a less pure material. Glass, for the purposes of the grinder, is better prepared by the use of proper moulds than by simple blowing, partly because the forms are frequently not so simple as to admit of their being made by hand, and partly because the various grooves and projections upon the surface can be roughly given by means of a mould without adding to the difficulty of blowing, and time and trouble is thus saved in the laborious operation of grinding. The moulds and the mode of using them resemble, in every respect, those which will be described under flint-glass or crystal.

Window-glass.—Properties.—Although window-panes may be made from any kind of bottle-glass that is not too much colored, just as many articles of bottle-glass are actually prepared from window-glass; yet, with reference to the object in view, a very marked difference is made in the mixture of ingredients. The amount of lime in the mixture must not be too small, that the panes may not be subject to become opaque when exposed to the atmosphere, whilst, on the other hand, any composition that has a tendency to devitrification would be a serious evil, as the glass has to be successively heated a great many times before it acquires the proper form for window-panes.

Production of window-glass.—The mechanical production of window-glass is effected with the pipe, either by blowing a hollow cylinder, which is cut open and flattened out, in a special operation, (*sheet or broad glass,*) or by distending, with the aid of centrifugal force, a more globular-shaped vessel attached directly to the pipe (*crown-glass.*)

Sheet-glass.—Cylinder-blowing.—The operation of blowing cylinders commences as usual with the collection of a sufficient quantity of metal from the pot at the end of the pipe. A massive glass ball is thus attached round the nob of the pipe which must be pushed forward with a *flatting-iron* until an annular groove is produced as at *a.* This operation completed, the blower rounds the ball on the marver, and distends it slightly by blowing. It then assumes the form represented in Fig. 2132, from which it will be seen that the mass of glass is thickest in front, as from that part it has to be distended and lengthened into a cylinder. In the subsequent operations, it first assumes the width of the future cylinder and then the length. With this object in view, the workman, after having rewarmed the ball of glass, holds it perpendicularly above his head, and blows into it. The heavy bottom yielding with less ease to the blast, admits of the distension of the width, and a flattened bottle is formed, Fig. 2133. As soon as the proper width is attained, the pipe is quickly inverted, so that the ball is undermost, and an incessant swinging motion is then kept up with a constant blast. Further distension is thus effected, but from the bottom only, as the thinner sides have by this time cooled, and in consequence of the swinging motion in the direction of the length, so that the bottle acquires the form represented in Fig. 2134, by the time that the glass has so far cooled as to be no longer expansible. If the swinging were admitted, the bottle would be distended in all directions, and present the form indicated by the dotted line. By repeated warming, swinging, and blowing, the form Fig. 2135 is gradually produced, which is then the proper length of the cylinder. It is then conical, and terminated by a semicircle, in the middle of which, at *c*, is the thinnest part of the vessel. When the workman blows air into the pipe, and closes the aperture with his thumb before withdrawing the pipe from his mouth, the air expands and exerts great tension upon the sides of the cylinder; if the weakest part, at *c*, is now held in the flame it will be blown out and burst. The cylinder having thus been *opened* as represented in Fig. 2136, the next object is to extend the somewhat uneven and thick margin of the aperture, and reduce it to the proper dimensions, whilst at the same time the other parts are straightened and acquire a uniform diameter, as is shown in Fig. 2137. Prominent portions which may sometimes project, are cut away with the scissors.

2132. 2133. 2134. 2135. 2136. 2137.

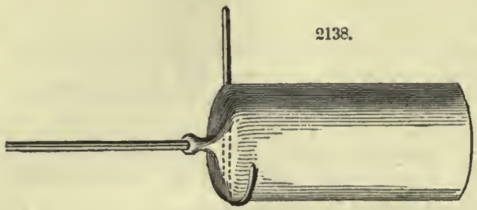


According to the size of the cylinder, it may be either blown at once, or it will require to be reheated several times. When very long and wide cylinders are blown, the lower portion is liable to become too thin; an extra portion of glass must then be incorporated with it before the opening process.

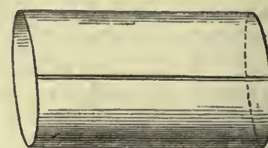
The neck and curvature where the pipe was attached to the cylinder have now to be removed, in order to spread the whole out in the form of a plate, and the cylinder must be cut open lengthwise. The cylinder, supported by an assistant upon a wooden rod, is, therefore, turned round two or three times in the curve of a bent iron, heated to redness, as shown in Fig. 2138, and a drop of water is

allowed to fall upon the heated line, which fractures the glass and detaches the cap. In a similar manner, but in a straight direction, a crack is made longitudinally, and the cylinder is then prepared for spreading or *flatting*, Fig. 2139.

2138.

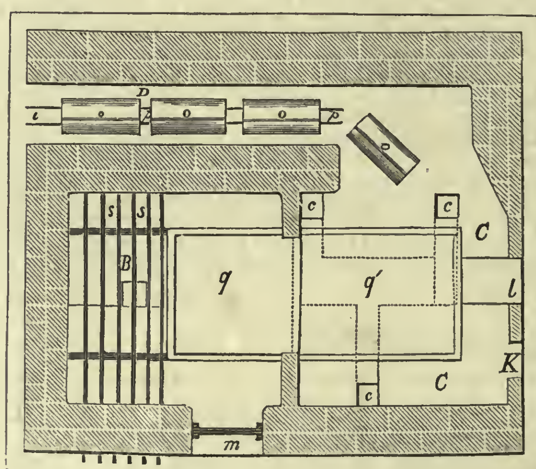


2139.



Furnaces constructed purposely, in separate buildings, are necessary for this operation, the principal parts of which are shown in horizontal section over the sole in Fig. 2140. The arched space A which extends the whole length of the furnace, comprising the ash-pit *a*, and the grate *r*; the former is accessible by the door *b*, the stokage is performed through *d*. The flame enters the upper space through the apertures *c c c c*, and first plays upon the flatting-hearth C before entering the annealing or cooling furnace B, which is also heated directly by the fire, when it escapes through the flue or channel D, by which the cylinders are introduced to be subsequently removed at *i*. The flatting-hearth and the cooling-furnace are connected with each other by a low-arched, wide aperture E, for the passage of the plates, as well as by a smaller, higher opening *g*, for the admission of the flame. The heat in the interior can easily be regulated by pushing plates over the apertures *c c*, and opening or closing the aperture *k*. The flattener stands in front of the aperture *l*, the workman engaged at the cooling-furnace before *m*, and an assistant in front of *i*, who pushes the cylinders *o o o o* along the railway *p*.

2140.



The most essential part of the furnace, however, is the *spreading-plate* or *flatting-stone q* and *q′*. This must be perfectly even, without any roughness or inequalities which would scratch the glass or make it lumpy; it must be inalterable in the fire, and of a size somewhat larger than the flattened cylinders. A plate of this description is usually manufactured from fire-proof clay mixed with cement, (either ground fragments of burnt clay of the same kind, or fine sand, or ground quartz,) strongly beaten during drying, then burnt, and lastly ground smooth; it is laid upon a bed of sand and in contact with a second table of the same sort in the cooling-oven. To make quite sure that no injury shall be sustained by the plates upon the flatting-stones, it is customary to cover this previously with a *Lager*. This is the name given to a thick plate of glass expressly blown for this purpose. These lagers are soon devitrified, which is of no moment, so long as the surface remains smooth; this, however, does not last long, and frequent renewal of the lager becomes necessary. Lastly, to prevent the cylinders from attaching themselves to the lager, the flattener, in some manufactories, throws a handful of lime into the furnace, which is carried as fine dust by the flame and spread over the lager. The temperature in the flatting-furnace must only be just sufficient to soften the cylinders; whilst in the cooling-furnace it must not attain that point.

The spreading operation is commenced by introducing the cylinders into the warming-tube D. The further the cylinders are pushed forward by those succeeding them the more they become heated, until they begin to soften on reaching the flatting-stone. They are then taken by the workman with a rectangular bent iron, and placed upon the lager with the cut side uppermost, where they open of

themselves, and are easily straightened and made even. For this latter purpose, a rod of iron, furnished at the end with a wooden polisher, Fig. 2141, is employed, and this is dipped into water each time it is used. When all the curvatures and lumps have been reduced, the sheet is pushed backwards into the annealing-oven, where it cools down and is placed in an upright leaning position by another workman. Between every 30 or 40 sheets, an iron rod *s s s* is inserted, and the operation is continued until the whole furnace is filled.

2141.

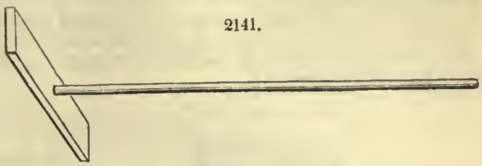
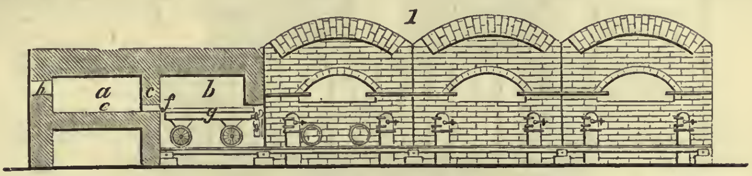


Fig. 2142, 1 is an elevation of a flatting-furnace in section, with three annealing-arches of the ordinary description.

Fig. 2143, 2 is a ground plan of the same.

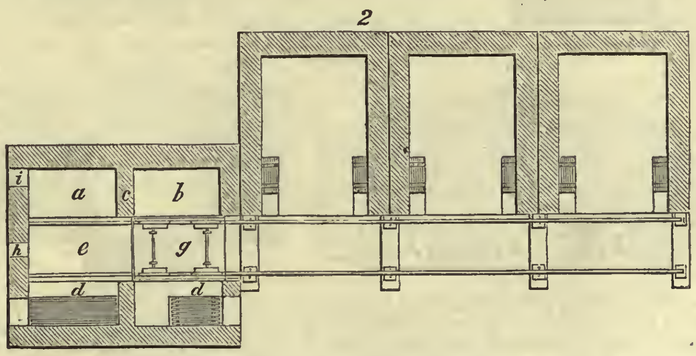
Fig. 2144, 3 and 4 are elevations of two end views of the flatting-furnace. *a b* is the spreading-furnace divided into two compartments by the partition *c*; *d d* are two sets of fire-bars, on which wood must be burnt; *e* is the spreading or flatting stone of the furnace, which must be perfectly smooth and even; *i* is an opening through which the cylinder is placed in the furnace previous to being laid on the flatting-stone *e*; *h* is the opening through which the workman spreads the cylinder into a flat sheet of glass; *f* is the opening through which the sheet of glass is removed to the table or bed *g*, in the compartment *b*. The upper side of the table *g* is made of stone, similar to that employed as the flattening surface. It is fixed to an iron frame-work on wheels, and is kept at a proper degree of heat by remaining in the furnace, as shown in the drawing. The carriage runs on a railway in front of the annealing-arches, where the sheet is transferred in the usual way.

2142.



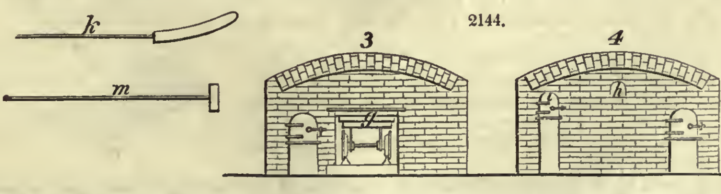
The cylinder is placed on the flatting-stone, and is split lengthwise by passing a red-hot iron bar *k* from end to end, having previously sprinkled a little charcoal powder on the inner surface of the cylinder. It is now spread out into a sheet by pressing the same on the flatting-stone, by means of a small block of elder-wood, fixed on an iron bar *m*. The temperature at which the flatting is performed is such, that the operation does not occupy more than a minute.

2143.



Two improvements have been introduced in this operation. One consists in making part of the floor of the compartment *a* to consist of a movable stone about 10 inches in diameter, on which the cylinder is placed. It is gradually exposed on all sides to the action of the fire, by causing the stone to revolve on its axis, and thus the objection to the previous plan is avoided where one side of each cylinder became so much hotter than the other.

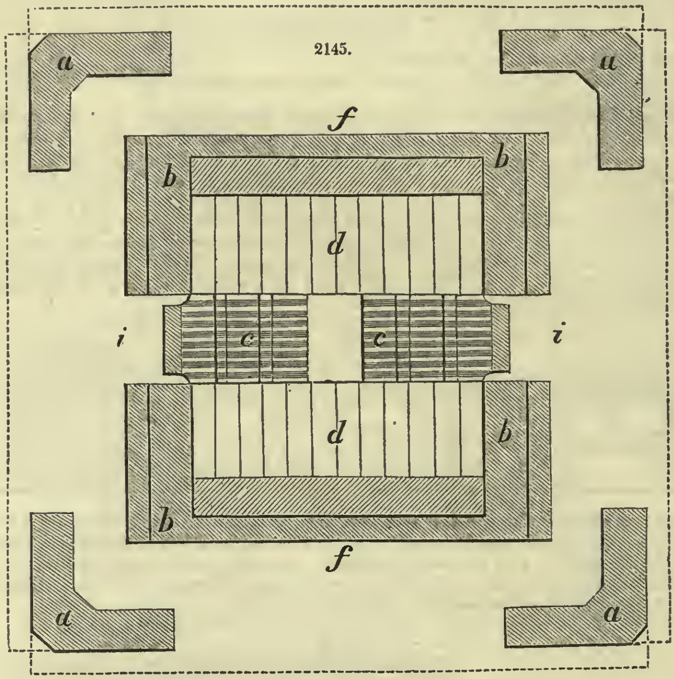
2144.



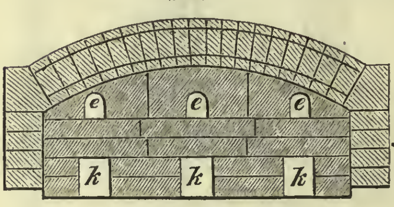
Crown-glass.—In the manufacture of crown-glass, in circular disks, a flattened vessel is first blown in front of a furnace specially constructed for the purpose, and this is converted, without any interruption of the process, into a round disk, thickened in the centre.

Figs. 2145, 2146, and 2147 show a ground plan of the melting-furnaces and the elevation of an end and side; *a a a a* are the stone pillars which carry the cone; *b b b b* the walls of the furnace; *c c* the grate-bars upon which the fuel lies; *d d* the "sieges," or position which the melting-pots occupy, one opposite each opening *e e e*; *g* is an elevation of the sides *f f*; and *h* an elevation of the ends *i i* of the furnaces; *k k k* are temporary openings to enable the workmen to insert large iron levers to assist in placing the pots, which are carried on a machine, in a red-hot state, into the furnace through the other temporary opening *l*.

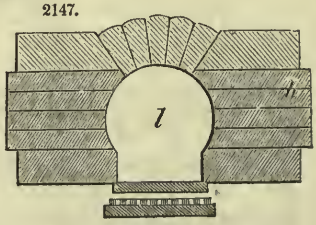
2145.



2146.

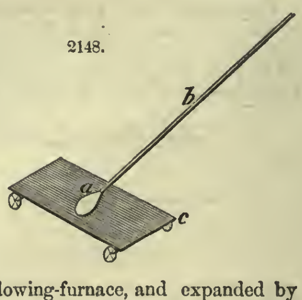


2147.



When a certain weight of glass, *a*, Fig. 2148, has been collected or gathered from the pots on the end of an iron tube *b*, it is fashioned into a peculiar form, as shown in the figure, on a solid plate of cast-iron *c*, also called a marver, although used for a different purpose to that mentioned previously. Previous to the operation of "marvering," the workman cools the iron pipe, which has become heated by being exposed in the melting-furnace.

2148.



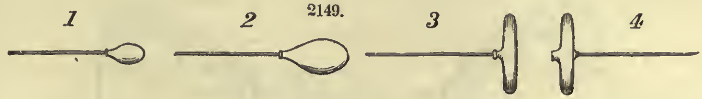
The marver *c* is placed on rollers for the convenience of moving it from place to place as required. When the mass of glass has assumed the proper form, a boy blows through the iron tube, while the workman continues to roll the ball upon the marver.

During the previous operation of "marvering," the mass of glass is fashioned so as to give the outer extremity a conical form, the extreme end of which becomes the outer axis of the globe during the operation of blowing. This outer axis is called the "bullion," and during the expanding of the globe, the workman rolls this bullion along a straight edge.

The piece of glass, after the above operation, is reheated, in the blowing-furnace, and expanded by the workman blowing through the iron pipe, until it is so far cooled as to require another "heat." When it has been blown to the proper size, Fig. 2149, 2, it is again exposed to the heat of the furnace, when the workman, resting the pipe on an iron support, during which time the neck remains cool, causes the

glass globe, by a peculiar motion of the pipe, to assume the shape shown in the figure, 3. This last operation is technically termed "bottoming the piece." It is then removed to a framing, Fig. 2150, where it rests on its edge on some ground charcoal and cinders *a*. Another workman then attaches a strong iron rod with a quantity of melted glass at its end, to the centre of the piece, as at *b*. The "blower" now touches the neck of the piece at *c*, with an iron rod previously dipped in water, and by a smart blow on the iron tube *d*, detaches the piece, leaving the neck open, as shown at 4.

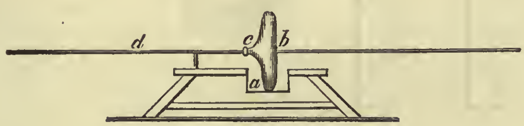
2149.



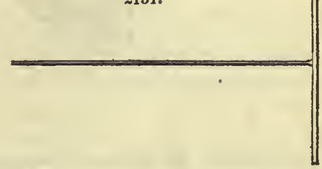
The "piece" is now removed to the "flashing-furnace." The thick neck is first heated at the opening, whence a powerful flame is issuing. Fuel is placed on the grating for the purpose of warming the "piece," while the neck is heated from the larger furnace through an opening in the side. As soon as the neck is sufficiently soft, a boy inserts a flat iron tool through the nose-hole, to smooth the roughness left in the neck by breaking it off as described above.

When the neck has been sufficiently heated at the nose-hole, the bell-shaped vessel is brought in front of another opening, where it receives the full heat of the flame, and the pipe is then made to revolve with the greatest possible rapidity. The action of this rotary motion upon the softened glass is easily conceived. The centrifugal force communicates to the particles of glass a tendency to fly off at a tangent, and to arrange themselves in a circular plane perpendicular to the axis of rotation. The mouth being the softest part, first expands, and this quickly increases until the whole suddenly opens into one sheet of glass, Fig. 2151, of about 6 feet in diameter, which, with the exception of the central

2150.

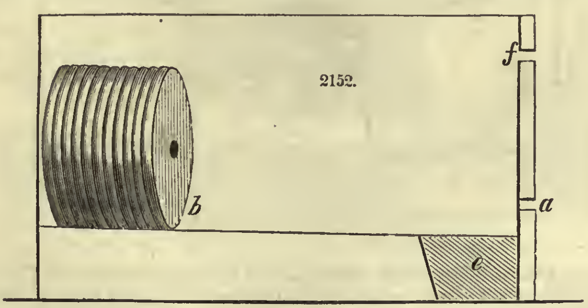


2151.



portion, is of nearly uniform thickness. It is obvious that a sheet of such dimensions must quickly fold together in the soft state, if the rotary motion is not kept up. The workman, therefore, continues the rotation after the removal of the sheet from the flame of the furnace, until it reaches the annealing-oven, where it is placed on a small circular bench, and is detached from the rod by means of a pair of strong shears, leaving a mark called the "bullion," or bull's-eye. Another workman, who has charge of the annealing, now raises the "table" of glass upon a large *fork-like* instrument, and carries it to an upright position in the annealing-arch, Fig. 2152. The tables stand thus on their edges, upon two strong parallel iron supports, which run the whole length of the annealing-kiln.

2152.



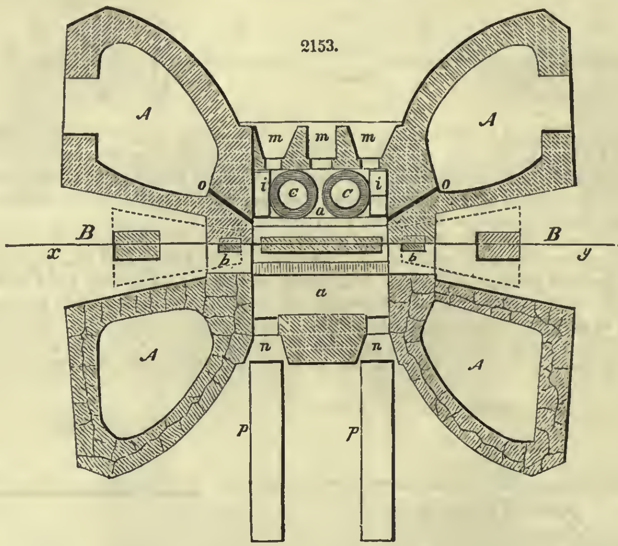
The glass, after remaining in the kiln for a considerable time, during which the cooling has been carefully regulated, is withdrawn, so as to enable a workman to go inside and hand out each table on the outside to an assistant.

Plate-glass.—The operation of blowing and flatting glass for mirrors is similar to that already described for window-glass, with some slight modifications rendered necessary by the greater size of the plates. The casting of plate-glass is a perfectly distinct operation.

The thickness of these plates, which are often 10 feet and more in length, must of necessity correspond with their extension; and that the light may be perfectly reflected from the metallic surface at the back, they must be as transparent and colorless as possible. To conform to such important conditions, the composition must consist of the purest ingredients, and afford a glass, the surface of which is quite unalterable when exposed to the air; if this is not the case, the plate becomes dull, loses its polish, and with this its transparency.

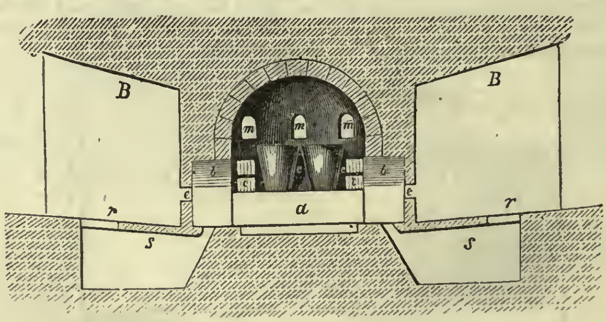
The following drawings of a plate-glass furnace exhibit the manner in which the fusing-pots are arranged, and also how they are inserted and removed. Fig. 2153 is a horizontal section at the height of the sieges to the right of *x y*, and somewhat lower to the left, through the holes for the cuvettes. Fig. 2154 is a perpendicular section through the line *x y*. The melting-furnace is surrounded by four side-furnaces A A A A, used for burning and heating the pots, and so arranged that the whole length

2153.



of the sides with the siege *a* is left open and free of access. Thus the two remaining sides are only accessible by the narrow passages B B, and these are connected with the large apertures *b b*. These apertures are used for the insertion of the pots *c c*, and, at the same time, for stoking the fire; for the latter purpose they would be too large, and allow too much heat to be lost; they are consequently bricked up above and closed in front by slabs of clay, with the exception of the small apertures *e e*. A grate is indispensable when coal is used, but this is not the case when wood is the ordinary fuel.

2154.

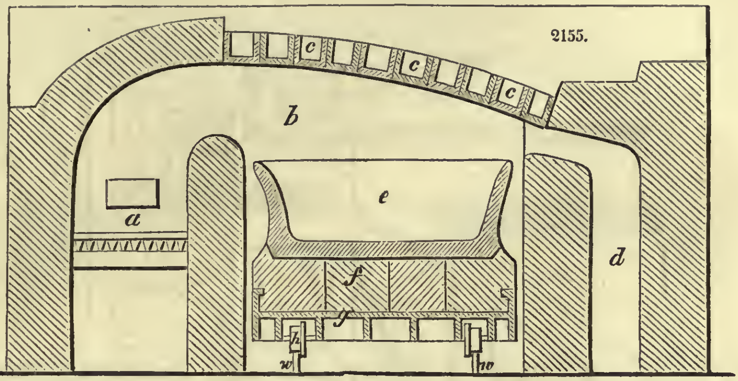


The flame travels from the melting-furnace, after passing between the sieges, and heating the pots *c c*, and the cuvettes *i i*, through the flues *o o* into the side-furnaces A. Two rows of holes are left in the free sides of the furnace. By means of the upper working-holes *m m m*, the melting-pots are accessible for the purposes of ladling; through the two lower holes *n n*, the cuvettes are inserted or removed upon the iron slabs *p p*, which must consequently be exactly upon the same level as the sieges. All the holes can be closed by movable plates at pleasure. The draught can be regulated through *r r*, and the ash collects in *s s*.

Mr. Bessemer has lately proposed a new method of casting plate-glass in sheets, by pouring the glass in the melted state directly from the pots between two rollers, placed at a certain distance from each other, so as to ensure a uniform thickness throughout. This is an invention which must commend itself to many in our country, as this art is but young even in England, and scarcely known here, but which must yet be extensively manufactured, as the means are not wanting, and the material is abundant in many of our states. At present our valuable plates are imported, and Germans are the artisans that are mostly employed in England. There are plenty of them in this country, and doubtless many good artisans capable of managing this business.

The pot-furnace and machinery for this process are entirely novel and very different from those in common use, and as the invention is likely to be carried out in practice, a notice of the most important parts of Mr. B.'s patent will not be out of place here. The furnace employed is a reverberatory furnace, Fig. 2155, with a low arch and descending flue *d*. The flame proceeding from the grate *a*, plays upon the surface of the materials in the pot *e*, in the fire-space *b*. The arch is formed at that part which is most exposed to the heat, and the alkaline vapors from the mixture, of hollow bricks *c c c*, over which a draught of cold air is caused to play, by connecting the space above the furnace with the ascending main chimney. The object of this cooling, which is of course attended with a loss of heat, is to prevent

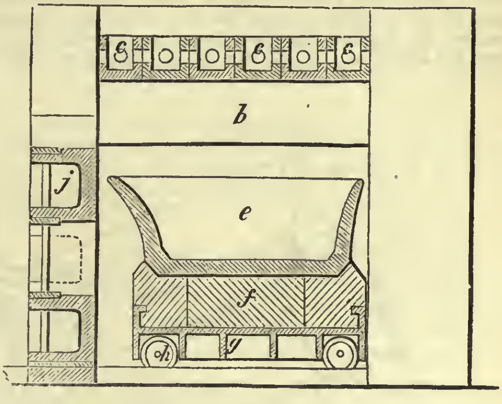
2155.



tears, consisting of the fusible product of the action of the alkaline vapors upon the ingredients of the bricks, from forming on the arch, and falling into the glass during fusion. The pot, *e*, is of very large dimensions, as large indeed at the lip on the one side as the width of the plates, which it is proposed to cast with it. It is set upon a siege composed of large masses of fire-stone, and these are cemented together, as well as the pot upon them, by some bottle-glass, which, in the fused state, enters the crevices and binds the whole firmly together upon the strong-ribbed cast-iron frame *g*.

This frame moves upon four wheels *h* upon a railway *w*, which extends beyond the furnace to the rolling machinery, to be described immediately. Thus pot, siege, and frame are all wheeled in and out of the furnace at once, as will be seen by reference to the section, Fig. 2156, where *i j* represent the hollow bricks, or masses of stone, by the removal of which a free ingress and egress is allowed the whole carriage on the continuation of the rail. The pot and carriage fill the entire recess in the furnace, and the flame playing upon the top does not much affect the iron frame of the carriage through the bad conducting-stones which form the bed of the pot. Fig. 2157 is a longitudinal section through the middle of the frame-work and machinery, by means of which the pot and siege are raised, and the melted glass poured out between the rollers.

2156.



The carriage consists of a strong-ribbed iron frame, mounted on four small flanged wheels which run on two rails. The upper side has a recess into which blocks of *soap-stone*, or fire-brick, are fitted into an iron frame. In the upper part of these blocks recesses are made for the melting-pots to sit snugly, and a quantity of broken bottle-glass is laid on the top of the blocks, and they are heated till the glass melts and cements the joints of the blocks together, and while this glass is yet in a fluid state, the carriage is removed a moment from the furnace to receive the melting-pot which is brought in a white-heat from the pot-arch, set in the midst of the fluid glass, and the carriage then returned to the furnace. On afterwards using the pot, as the bottom is very thick and the heat only having access to it through the materials which it may contain, the bottle-glass used to cement the pot to the bed or recess is found not to be too cold to be brittle, nor so hot as to allow the pot to slip from the carriage.

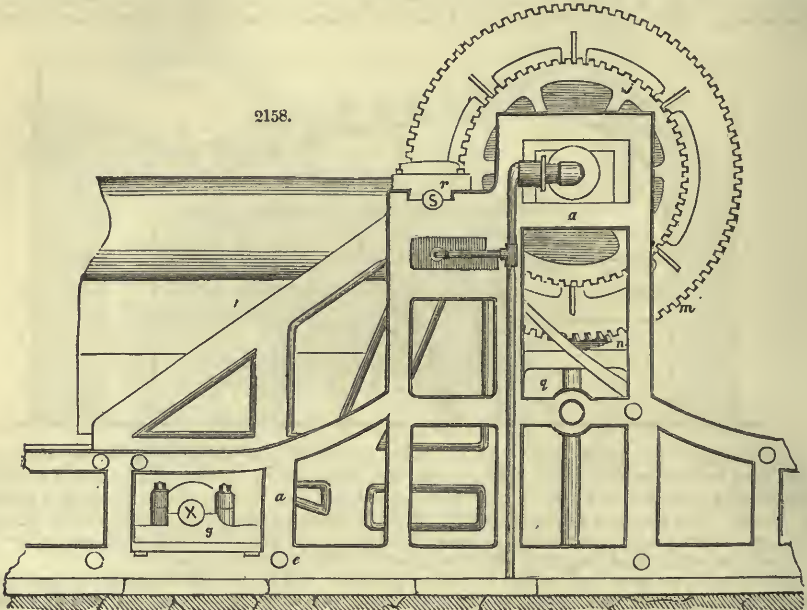
Fig. 2158 is a side elevation of the machine, with the pot and carriage in their position after being removed from the furnace.

Fig. 2157 is a longitudinal section showing the pot in an elevated position and partly emptied.

Fig. 2159 is a longitudinal section of one of the rollers and stuffing-boxes, showing how the water is made to enter and leave while they are in motion. *a a* is a side framing of cast-iron secured by the cross-pieces *c*, and also by the stretchers *e e*, between the side-frames *a a*. The rollers *f* and *g* are placed in suitable bearings fitted to the side-frames, and are made to move to and from each other by means of screws, which force the brasses H and roller *f* near to the roller *g*. A

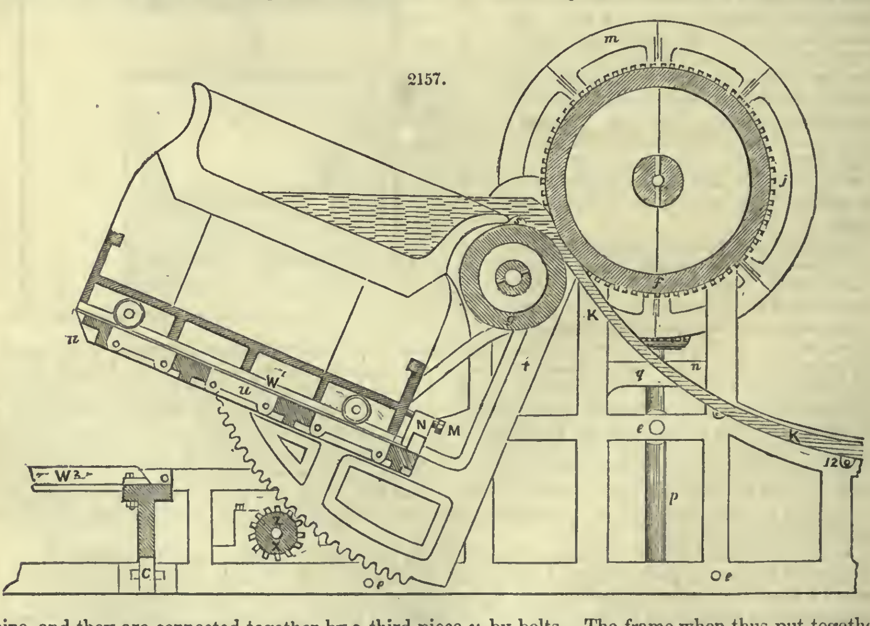
piece of iron is placed between the brasses and the frame, and according as it is exchanged for one of more or less thickness so will it cause the rollers to be nearer or further apart, and thus regulate the thickness of the glass. The roller *f* is also provided with wheels *j j* at each end, and the roller *g* also with wheels at each end within the side framing. In addition to these wheels, the axis of the roller *f* has on the outside of the framing a large bevel-wheel *m*, driven by a pinion *n*

2158.



on the end of an upright shaft *p*, driven by an underlying shaft from the main driver. The upper part of the shaft *p* is supported by a bracket *q*, projecting from the side-frame; near the upper part of the framing there are two plummer-blocks *r*, which form a support to the pins which project from the side of a piece of tilting-frame. There are two of these pieces *t*, one on each side of the ma-

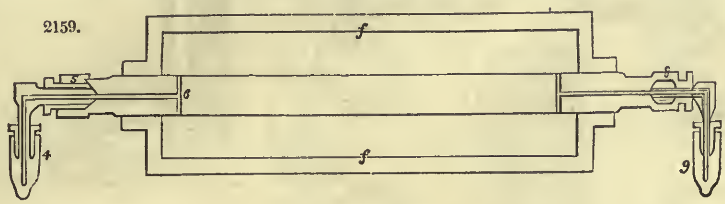
2157.



chine, and they are connected together by a third piece *u*, by bolts. The frame when thus put together is supported by pins *s s*, and occupies nearly the entire width between the side-frames *a a*. The lower part of the piece *t* has a segment of a tooth-wheel formed on it and centred on the pins *s*, so that the

tilting-frame may move a portion of a circle on these pins. The piece u has two small ribs or rails extending across and cast upon it, which form a continuation of the rails which conduct to the furnace. X is a shaft extending across the frame supported by plumber-blocks y, attached to the side-frames e, which shaft x has pinions z upon it geering with the segment of the tilting-frame t. The shaft x is also elongated to a convenient distance, and supported at its extremity by a frame of two side pieces connected by stretchers. The upper part of the frame carries two plummer-blocks and a shaft; the shaft having a handle and a pinion upon it, which geers into a large spur-wheel on the shaft X. By turning round the handle on X it forcibly raises the tilting-frame with any object that may be placed on it. There is an opening in the tilting-frame through which the axis of the roller g passes; and this roller is sufficiently long to allow the required movement of the tilting-frame. The rollers are supplied in this machine with water to keep them cool; the water is conveyed below the floor to the pipe 1; at 2, there is a branch which leads off from 1 to the axis of the roller g, which it enters through the stuffing-box; the tube 1, proceeding further upwards, bends over and forms another stuffing-box 4, which allows the upper roller f to move a small distance horizontally, to alter the thickness of the plate. The water

2159.



enters the axis of the roller f by passing through the stuffing-box 5; the axis of the roller is not hollow throughout, but the hollow part of it terminates at 6, Fig. 2159, where there are two side holes bored at right angles to it, which allow the water to pass into and occupy the large hollow space in the body of the roller. By a similar contrivance the water is allowed to flow out of the opposite end of the roller, passing through the stuffing-boxes 8, 9, and, descending the pipe, is conveyed away under ground. A strong curved plate K extends the entire width between the said frames, fitting closely up to the roller g, and secured to the frames by lugs. On this plate the sheets of hot glass slide down towards the flat bed, but which is broken off in the cuts; the side of the melting-pot nearest to the machine has a curved lip, so as to overhang the roller g nearly as far as the centre. The pin s of the tilting-frame is at its centre a little above the upper side of the roller g, so that the lip of the pot being in the position shown in Fig. 2157, it does not shift from that spot far, as it may be tilted up.

The mode of operating with this apparatus is as follows: When the glass is in a fit state for casting, the door is removed by a crane from the mouth of the furnace, and by the assistance of an iron hook the carriage and its pot are easily rolled forward upon the rails before mentioned to the tilting-frame t; then they occupy the position shown in Fig. 2158. The carriage and its pot are now moved forwards until the set screws M come in contact with the carriage; the office of these screws is to regulate the extent to which the lip of the pot shall overhang the roller g, so that when a new pot is used its proper position for pouring may be adjusted. The screws M pass through stout lugs N, cast on the piece u; the handle on X being turned, the pot will be elevated, as shown in Fig. 2157, when the glass passing between the rollers will be formed into sheets. When the pot is emptied it is again lowered and returned to the furnace for a repetition of the preceding operations; the roller f is furnished with a rib on its circumference, which is the whole of the roller; this at each revolution cuts the glass off into lengths.

Lead or flint glass (so called because flint was first employed in the manufacture) is peculiarly adapted for articles of luxury, such as goblets, chandeliers, decanters, &c., from the ease with which it is ground or cut, from its brilliant lustre, high refracting power, and perfect freedom from color. The mass which is used for this purpose is called, in a more limited sense of the word, crystal, (from its resemblance to rock crystal,) and it excels the Bohemian grinding-glass (crown-glass) with reference to refractive power and easy fusibility, although the latter is harder and more completely colorless.

As nearly all the articles composed of flint-glass, or crystal, require to be ground, in order to exhibit their greatest brilliancy, they must be constructed in a very massive form; there is consequently more necessity for avoiding all sources of color, and for preparing the glass from oxide of lead, potash, and silica alone.

The fusion occupies six or eight hours, and the fining, which is very much facilitated by the easy fusibility and the purity of the materials, requires about the same time.

During working, the glass must be protected from the smoke of the furnace, and iron must not be brought into contact with it, as it otherwise infallibly becomes of a dark-brown color. Iron is dissolved by the glass, taking the place of the lead, which separates as metal in the most minute state of division.

The construction of furnaces and melting-pots in manufacturing flint-glass are somewhat different from those employed in the other descriptions of glass.

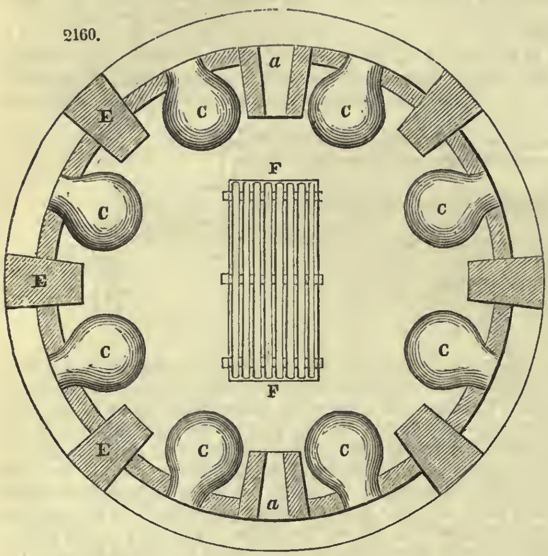
Fig. 2160 is a ground-plan of the melting-furnace; C C C are the pots which are situated at equal distances between the pillars or piers E E which support the exterior dome. a a are the openings in two of the piers for charging with fuel.

Fig. 2161 is designed to show how the heat is carried round the pot in its exit from the furnace. The pots are covered with a hood-shaped top, and these fit the working-holes of the furnace, so that the smoke and heat cannot escape in the same way as in the usual glass-furnaces; a is the pot with the top

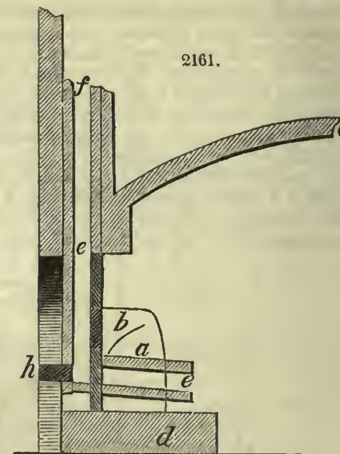
b; *c* is the roof of the furnace; *d* the "siege" on which the pots are placed; and *e e* a flue, low down, which passes between the furnace and the cone till it reaches a point *f* where it enters the cone itself. *g*, Fig. 2161½, is a front view of the pot and arch of the cone, which allows the workmen to approach the opening in the furnace, against which the mouth of the pot is placed; *h* is an opening direct from the outside into the flue, for the purpose of keeping it clean.

Fig. 2162 is a general view of the melting-furnace, cone,

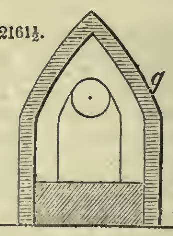
2160.



2161.

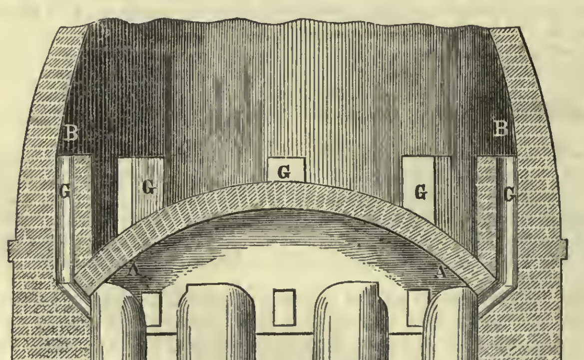


2161½.

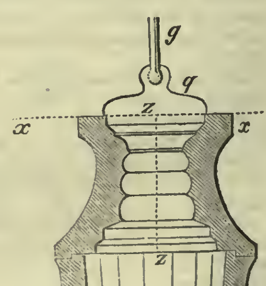


and working-holes. It consists of two domes, A A, B B, one within the other, of which the interior one is flat, and the exterior of considerable altitude, terminating in a high chimney. The only connection between the domes is by the flues G G, which are situated one on each side of the crucibles, so that they receive the whole body of the flame as it passes from the fire-place to the exterior dome, and thence to the chimney.

2162.



2163.

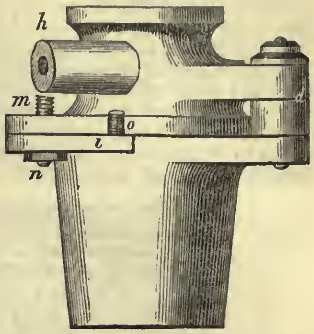


Flint-glass is either formed by simple blowing with the pipe, by blowing in moulds, or by moulds alone; in every case the form can be improved, as is generally done, by grinding, &c.

The moulds are carefully constructed of brass or iron, and are somewhat wider at the upper part, when of simple construction, that the pieces may be easily removed, or are composed of more than one piece when projecting parts are to be moulded. A mould of the latter description is represented in

Fig. 2164, intended for a decanter; a section of the mould is shown in Fig. 2163. The bottom *e* and the sides *a* of the body form the lower and larger part of the mould, and are held together by the screws *b b*; the upper smaller part consists of two halves, meeting in the line *z z*, which open after the fashion of a pair of tongs when turned upon the hinge *d*. That they may not be extended more than is necessary, the two wings are impeded by the plugs *o* fixed to the ring *i*. The workman introduces the glass globe *g*, attached to the pipe, into the body of the mould, the neck portion being thrown open, and blows with great force into the globe, as soon as the neck portion has been closed by an attendant, and fixed by the screw *m*, (the female screw belonging to which projects at *n*.) The glass is now forced, by the pressure, against the sides of the mould, and extends in the form of a cap at *g*, above the margin, where the pipe is detached in the direction of *x x*. The cylinder *h*, and another similar one, more at the back, are intended for the insertion of wooden handles. Massive pieces, such as plates, are formed by pouring melted glass between two plates of metal composing the mould, and the excess of glass is squeezed out from the crevices by applying weights to the mould.

2164.



All articles of flint-glass, whether blown, moulded, or pressed, require annealing previous to cutting or grinding, and as they are frequently constructed of very different thickness, two kilns, which can be heated to different temperatures, are requisite; the larger and thicker pieces require that the kiln should be much hotter than is necessary for thinner pieces. These kilns are long, low buildings, arched over on the top. The various articles are all placed on sheet-iron trays. These trays are put into the kiln, through the opening in front, and are all connected together by hooks, by which means they can be moved by a chain, worked by windlass or similar machinery, to the further end of the kiln, and are thus gradually withdrawn from the hottest part, and, having arrived at the further extremity, are removed at a temperature little above that of the atmosphere.

Moulded or pressed glass never exhibits its full amount of lustre, nor even the degree of sharpness of the metallic mould; the glass, which is never limpid in its liquid state, is first cooled by contact with the metallic surface, and is thus prevented penetrating into the sharp corners of the mould, nor does it even accommodate itself perfectly to the flat sides. For this reason, the surface of moulded glass is not even, but always more or less curved, and the edges are not sharp; but the use of moulds as a preparatory step to grinding, is of great advantage to the grinder, as the vessel acquires a perfectly regular form, and, although in a crude state, presents all the prominent and receding facets to be perfected at the lathe.

The ordinary utensils used in *grinding* or *cutting* glass, are disks of iron, sandstone, or copper, which revolve in a kind of *lathe;* their edges, which are sharp, angular, or rounded, are supplied with sand for *rough grinding*, and with emery for *fine grinding*. Similar disks of tin, wood, or cork, used with pumice-stone or colcothar, are employed for polishing the glass. It is obvious that not only disks with very different edges will be required, but also disks of very different dimensions, from 8 to 10 inches in diameter, (½ to ¾ of an inch in thickness.) For inscribing initials, designs, &c., disks of copper of the size of a cent are employed, with oil and emery; the finest incisions are made with copper pencils, either pointed or ending in a button or small disk.

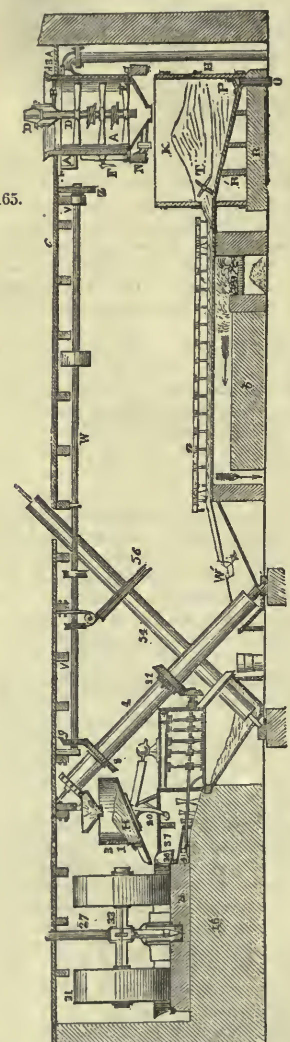
Bessemer has lately taken out a patent in England (1848) for the manufacture of plates, sheets, and panes of glass, which is of sufficient importance to merit a place here in full.

This invention relates, first, to the arranging of machinery for washing, drying, and sifting sand, and afterwards grinding or crushing the same in combination with the other materials employed for making sheets, plates, or panes of glass. Secondly, to the employing an additional pair of rollers to the machinery now used to roll glass into sheets. Thirdly, to a method of heating annealing-kilns or lears. Fourthly, to a method of smoothing or polishing plates, sheets, or panes of glass, whereby an endless belt or strap (charged with polishing material) is made to pass rapidly in contact with the surface of the glass, and to traverse slowly across it in a direction at right angles to the line of its quick motion; and lastly, to a method of producing plates or tables of glass of the description known as crown-glass, in such a way that the centre of the table shall not have a bullion or knob as usual. First, with regard to the method of washing, drying, and sifting sand, and afterwards grinding or crushing the same in combination with chalk, alkali, charcoal, or other matters used for making sheets, panes, or plates of glass. To accomplish this object, the patentee uses the apparatus represented in Fig. 2165, a longitudinal section of the apparatus; Fig. 2166 a longitudinal or side elevation, and Fig. 2167 a plan of the same. The letters of reference denote the same parts wherever they recur in each of the figures. A, is a cylindrical iron vessel, having an annular trough or channel formed around its upper edge at A′; this channel is strengthened by brackets A^2, and has a flange at its upper edge A^3, to which the mouth of the vessel B is attached by bolts; this mouth-piece has three arms B′, B^2, and B^3, meeting in the centre boss C, which is bushed with brass, and so shaped internally as to form a bearing and support for the shaft D, which has a conical collar at D′, resting in the brass bush C, to prevent its dropping downwards. As the lower extremity of it has no support, the bush C is elongated upwards so as to form an oil-cup, and is covered by the piece C′, which revolves upon the shaft, and prevents any sand from falling into the oil. The shaft D passes upwards to any convenient height, where it turns in other bearings, and has keyed upon it a bevelled wheel, into which are geered two other bevelled wheels, mounted on a shaft proceeding from any first mover. The office of these wheels, but which are not shown in the engraving, is to communicate a rotatory motion to the shaft D, in either direction, by the shifting of a clutch in the manner well understood and practised in reversing geer. The shaft **D** is

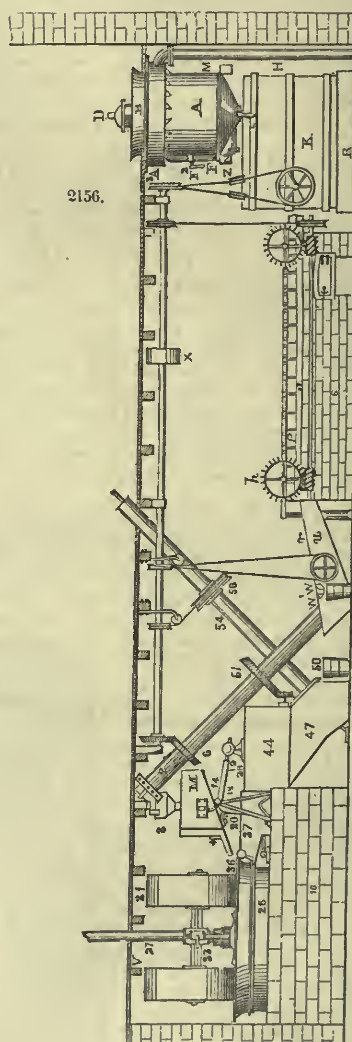
provided with a number of radiating arms or blades E, placed at such an inclination as to form each a portion of a spiral, and will therefore have a tendency when revolving in one direction to lift any matters they may be moving among, and also have a tendency when revolving in the opposite direction to press such matters downwards. F is a pipe to convey water from an elevated reservoir into the lower part of the vessel A; this pipe is provided with a cock at F′ and handle F^2.

In Fig. 2165, it will be seen that the vessel A and its mouth-piece B, although screwed together at the outer flange A^3, do not come in contact at A^4, whereby a circular space or opening is left all round the vessel, communicating with the trough A′. The action of this part of the apparatus is as follows:— The sand to be used for making glass is conveyed along the floor G, of the upper room, and emptied into the vessel A, until the vessel is at least two-thirds filled; the shaft D is then put in motion in the direction to lift the charge; at the same time, the cock F′ is opened, and water is allowed to flow upwards through the body of sand, while the blades E keep lifting and turning it over. As soon as the water

2165.



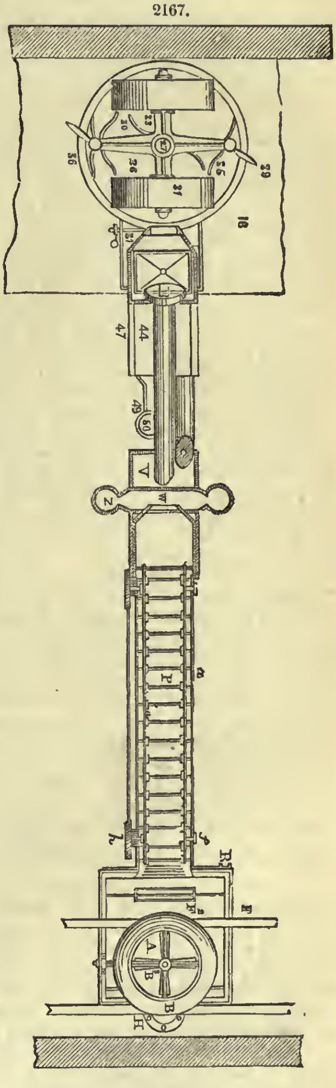
2156.



reaches the outlet A^4, it flows over into the trough A′, carrying with it such foreign matters as are soluble in water, or easily mechanically mixed therewith; the water is allowed to escape from the trough by the pipe H, leading to a culvert underground. When the water flows off clear, the cock F′ is closed and the throttle-valve J is turned at right angles to the position shown in Fig. 2165, and the shaft D being caused to revolve in an opposite direction, the sand will be forced downwards and expelled into the wood-back or cistern K. The valve J being again closed, the operation may be repeated. The valve J is a disk of wood covered at its periphery with leather, in order to make it water-tight, and moves on an axis I, and has a handle L, by which it is moved when required. The vessel A is fastened by a lower flange M. to the transverse timbers N, inserted in the walls of the building, and is further

steadied at the part where it passes through the upper floor G. The cistern K has a slanting bottom to facilitate the drawing off of that portion of the water which is admitted with the sand at the lower end. There is a fine grating of pierced zinc P, covered with felt, so as to prevent the sand being carried off by the water which flows through the pipe O into a drain. The cistern K is supported on timbers R, and others placed crosswise at R′; one side of the cistern has a rectangular opening S, behind which is placed an agitator T, mounted on an axis T′, which extends through the sides of the cistern, and carries at one end the pulley-wheel U, which is put in motion in the following manner. Beneath the rafters V, of the upper floor G, is the shaft W, receiving motion from any first mover by a strap passed over the drum X; this shaft is supported in plummer-blocks Y, bolted to the rafters V, and carries a pulley Z, from which a catgut or other band passes over the guide-pulley Z′, and on to the pulley-wheel U, and thereby causing the agitator I to revolve in the direction of the arrows and expel a portion of the wet sand on to the drying-plate: *a* is a plate of copper, or galvanized iron, having a raised edge *a′* on each side to prevent the sand from falling off; beneath it is the furnace *b*: a fire is made at *c*, and the products of combustion are allowed to flow under the plate *a*, as shown by arrows, and to descend the downward flue *d*, into an underground flue, leading to a chimney. On each side of the plate *a* there are small bracketed projections *e*, on which are bolted the bearings *f*; in these bearings the cranks *g* are caused to revolve by means of the worm-wheels *h*, which are keyed on the crank *g*, and are geered into worms *i i* on the shaft *j*: this shaft revolves in bearings *k k*, and has a pulley-wheel *l* fixed upon it, which receives motion from another pulley-wheel *m*. On the shaft *w* a light iron frame *n* is supported by the cranks *g*; this frame has a number of scrapers *p* fixed crosswise upon it, so that the frame *n*, which always moves parallel with the plate *a*, by the motion of the cranks, is made to dip its scrapers into the sand at every revolution of the crank, and to impel it forward on the plate, turning it over, and always advancing it in little heaps, further along the hot plate. The speed of this part of the apparatus is to be so regulated that the moisture is evaporated by the time it arrives at *q*, where it falls from the plate *a*, on to a sieve *r*, in a dry state.

2167.



The wire sieve *r* is hung upon a joint at *s*, and has a small shaft *t* below it: this shaft has upon it a tappet-wheel *u*, which lifts up the sieve a short distance and lets it fall suddenly in quick succession, so as to shake the sand through it on the inclined bottom of the bin *v*. The shaft of the tappet receives its motion from the pulley *x*, on the shaft *w*, which, by means of a band, communicates with the pulley-wheel *y*, keyed on the shaft *t*. Such matters as shells, stones, &c., as are mixed with the sand and are too large to pass through the sieve *r*, fall off from it into the trough *w*, which is raised in the centre at *w′*, and allows any matters falling into it to roll into the vessels *z*, from which they are to be removed, as occasion may require. The sand, by the operations just described, arrives in the bin *v* freed from small earthy particles by washing, and screened from all larger particles than grains of sand, and being in a dry state is now fit for the grinding operation; and to facilitate its removal to the mill, and to regulate the quantity forming one charge, the following contrivance is resorted to. The sand is first raised by means of the archimedean screw 2 into the receiving-hopper 3. This screw has a central shaft 4, passing, at its lower end, through the bottom of the bin *v*, and resting in a bearing 5, let into a block of stone 6, below the floor. The upper end of the screw-shaft rests in a plummer-block 7, bolted to one of the rafters V. Near the top of the screw there is a bevelled wheel 8, which is actuated by another wheel 9 on the shaft W. The rotary motion thus transmitted causes the sand to ascend the spiral path of the screw, in a manner well understood when applied to other purposes, and finally to discharge itself into the receiving-hopper 3, which is secured to one of the rafters V, by an iron strap 10.

Below the receiving-hopper there is another hopper 11, of larger dimensions, having its bottom inclined to one side, where it terminates in a wide spout 11*. This hopper 11 is not fixed like the one above it, but is supported on scale bearings at 12, projecting from an iron plate 13, bolted to the hopper 11. There is one of these pieces on each side of the hopper resting on the forked end of the arms 14*; these arms are keyed on to a shaft 14, which is supported in bearings 15*, formed on the two iron standards 15; the standards are bolted on to a raised piece of masonry 16, and are steadied at their upper ends by a stretcher 17, extending across from one to the other. From the centre of the shaft 14 there projects a lever 18, the end of which is screwed and passes through the adjustable weight 19; in

order to prevent the hopper 11 from tilting over, it has an arbor 20, projecting downwards from the under side of it; at the lower end of the arm, there is a roller 21, which moves up and down between two guide-bars 22; 23 is a support for the weight 19 to rest upon. The hopper 11 thus supported, forms a sort of weighing-machine, in which the quantity of sand required for one charge of the mill is determined. Its operation is as follows:—The apparatus being in the position represented in the drawings, the sand is seen flowing from the receiving-hopper 3 through an opening in the bottom of it. This opening is provided with a plug 24, formed with hollow sides, in the manner usually practised with the tails or spindles of cone-valves; but as these hollows or flutes do not extend the whole length of the plug, it is capable of entirely closing the orifice if pulled down. This plug is attached to a small chain and rod 25. Now so soon as the accumulated weight of sand in the hopper 11 is sufficient to counterbalance the weight 19, it will do so, and will lower itself until the stop 20* reaches the guide-bars 20, where it will rest. In moving down, the hopper will draw down the plug 24, by means of the chain 25, and prevent any more sand entering it. During the time the plug-hole is shut, the sand, which is regularly brought up by the screw, will accumulate in the hopper 3.

In order to regulate the exact weight of sand in the hopper 11, the weight 19 may be screwed further off, or nearer to the axis of the lever. 16 is a piece of masonry, raised above the general level of the floor; on it is placed the horizontal bed-stone 26. This bed-stone is part of an edge-stone mill, constructed on the general principle of such mills. 27 is a vertical shaft, running in a brass step 28, at its lower end, and passing up through the floor above, where it is supported by another bearing, and carries on its upper end a bevel-wheel geering with another bevel-wheel on a shaft, actuated by any first-mover. These wheels the patentee has not shown in the drawings, but they are well understood. The brass step 28 is elongated upwards, forming a sort of tubular oil-cup; surrounding the shaft, there is another tubular piece 29, closed up at top, and attached to the shaft. This tube 29 is inverted over the oil-cup, and reaches nearly down to the bed-stone, so as to prevent any powder working into the oil-cup. To the outside of the tube 29, there are attached two curved plates or scrapers, shown at 30, Fig. 2167, for the purpose of removing the materials from the centre of the bed, and distributing them in the path of the stones 31. On the shaft 27, there are four cast-iron arms, united by a central boss fitted loosely to the shaft 27, but made to turn with it. In consequence of a projection or feather 32, two of the arms 33 carry with them the edge-stones 31, mounted with proper bearings, through which the arms pass. In rolling over any matters in their path, these stones can rise up, carrying with them the arms and boss on the shaft 27. The other two arms 34 carry at the extremity two small axles 35. These axles have at their lower ends the scrapers 35*, by which the materials under operation are brought from the curb or outer iron ring 36, into the path of the "runners."

When one charge of materials has been ground, they are removed to the receiving-box 27. For this purpose, a portion of the iron curb 36* is mounted on a joint 38. An elongation of the joint-pin is seen at 39, where it extends through the receiving-box 37, and has a lever and weight 38, for the purpose of retaining it either up or down. When it is moved down, as at 36*, it allows the ground materials to be passed into the receiving-box. The better to accomplish this end, the handles 39 have to be pulled in the opposite direction to that shown in the drawing, so as to reverse the scrapers 35*, as shown by dots in Fig. 2167. The scrapers then cause the materials to pass through the opening in the curb 36*. When this is accomplished, the jointed piece 36* of the curb is moved upwards, and retained in that position by the counter-weight 38, the scrapers 35* are restored to their former position, and the mill is in readiness for another charge of materials. To do this, the sliding-door 40 of the hopper 11 is lifted up by the handle, and the charge of sand weighed in the hopper 11 is allowed to fall into the curb surrounding the bed-stone. The diminution of weight in the hopper 11 will allow it to ascend into the position shown in the drawing. When it is emptied, the slide 40 is to be shut down, and the plug 24 lifted up so as to allow the accumulated sand in the receiving-hopper 3 to fall into it. The refilling of the hopper 11 takes place while the grinding of the former charge is going on. When the sand is nearly reduced to the required degree of fineness, the soda, potash, or other alkaline matters, are to be added, and also the chalk, lime, charcoal, or other matters required in glass-making, each in their proper proportions according to the description of glass intended to be made. The materials are to be left in the mill until the greater part, if not the whole, of the matters are ground to a fine powder, when they are discharged into the receiving-box, as before described. He here remarks, that when alkaline salts are used, their water of crystallization should first be driven off by exposing them to heat.

The next operation to be performed is, to separate any imperfectly ground portions of the materials, and to return them back to the mill to be again operated upon. This may be returned and worked with the next charge each time. Below the box 37 is fixed a plummer-block 41, which receives one end of the shaft 42, the other end being supported in a plummer-block 43, attached to the case 44 of the bolting or dressing apparatus. The shaft 42 has fixed upon it a number of brushes 45, arranged so as to touch the wire-gauze drum 46, as they revolve in a similar manner to that already practised in dressing flour and other matters. Such particles as are fine enough to pass through the wire-gauze fall into the bin 47; but those particles which are too coarse to pass out at the end of the drum at 48, are conducted by the spout 49 into the receptacle 50, and may be re-ground as before mentioned. The shaft 42 receives its motion from a bevel-wheel 51 on the archimedean screw 2, which geers into the wheel 52 on the shaft 42. The wire-gauze cylinder may be made to vary in fineness, according to the desire of the manufacturer; but that which the patentee prefers is a range of fineness between five thousand and ten thousand holes in the superficial inch. The wire-drum is supported by hoops 53 which surround it, and is further protected externally by its case, 44. The shaft 42, at the part where it passes through the receiving-box 37, is provided with inclined blades, which, as they revolve, assist in bringing fresh supplies of materials through the opening 37* into the wire-drum. The dressed or finished materials which fall into the lower part 47* of the bolting or dressing apparatus, are raised to the upper floor by means of an archimedean screw 54, in the way already described for elevating the sand.

This screw is shown in elevation, its internal structure not differing from those in general use for raising malt and other materials. In Fig. 2167 it is shown as being cut off on the line A B of Fig. 2165, so as not to obstruct the view of the rest of Fig. 2167. The screw 54 receives motion from a pulley-wheel 55 on the shaft W, the band from which passes over a pulley-wheel 56, on the screw-shaft, the band being directed in a proper course by the intermediate guide-pulleys 57. The screw, after passing through the upper floor, (where it is shown broken off,) may either be made to deliver the prepared materials on to the floor, or by raising them a little higher, deliver them into a large bin or other receptacle, the upper end of the screw being supported in a similar manner to that used to support the screw 2 at 7. Having ground or crushed the materials above mentioned, the callet or broken glass is supplied, as heretofore, in the manufacture of like glass. The advantages of this method of preparing the materials to be used in the manufacture of sheets, plates, or panes of glass, are, first, a saving in manual labor in the operation of washing, drying, sifting, and weighing; and secondly, the minute mechanical division of the various matters used will facilitate their chemical action, and therefore save both time and expense in their formation into glass. Secondly, with regard to the use of an additional pair of rollers to such machines as are used to roll glass into sheets, for the purpose of either rendering the cast or rolled plate more smooth and uniform, or for the purpose of impressing or embossing any designs thereon. Thirdly, with regard to his method of annealing and of heating annealing-kilns or lears, by the introduction therein of air, heated in pipes or other suitable apparatus after the manner practised in heating air for hot blast in the manufacture of iron, which consists in an apparatus for annealing sheets, plates, or panes of glass. Fourthly, with regard to a method of smoothing or polishing plates, sheets, or panes of glass, by an endless belt or strap charged with polishing material, which belt is made to pass in contact rapidly over the surface of the glass, and to traverse slowly across it in a direction at right angles to the line in which the belt moves over the drums that impel it. The improvements under this head consist in an apparatus for smoothing or polishing the surface of glass after it has been ground in the usual manner. For this purpose he constructs the machine or apparatus in such a way that the polishing-rubber or frictional surface passes rapidly and continually in one direction over the surface of the glass, and is made also to traverse slowly backward and forward crosswise over the same surface, the glass being laid on a stationary table of slate or other suitable material.

Process of manufacturing flint-glass and crown-glass for optical purposes.—P. L. Guinand, senior, of Brenriets, in Switzerland, was the first who discovered a special process for this manufacture; and he has succeeded in manufacturing crown-glass equal in quality to flint-glass; that is to say, free from striæ, from bubbles, from threads, and which does not attract moisture.

The invention of M. Guinand, senior, consists in working and stirring the material while in a state of fusion, by means of a tool made of the same material as the crucible or glass-pot. He made a hollow cylinder of fire-clay of the same height as the crucible, closed at its lower extremity, open above, with a flat ledge all round of several centimetres in width. Having heated this cylinder red-hot, he placed it in the melted glass; then, by means of a long bar of iron, bent to a right angle at a distance of some centimetres from its extremity, which he introduced into the cylinder of fire-clay, he worked and stirred the glass, by giving the bar a horizontal rotary motion.

For the manufacture of flint-glass, and of crown-glass, he adopted a circular furnace, in the centre of which is placed the crucible or glass-pot, all the parts of which are exposed to the same temperature; and covered crucibles are adopted, because with crucibles of this form there is no danger of the glass being spoiled by particles of the fuel, or by drops, or tears from the crown or arch of the furnace.

The success of the operation depends very much on the form and proportions of the furnace and crucible.

Figs. 2178 to 2170 represent the furnace, the crucible, the cylinder of fire-clay, the bent iron bar and its support.

Flint-glass, of the usual density, similar to that used for table-sets, decanters, &c., is composed, ordinarily, of 300 parts of sand, of 200 parts of deutoxide of lead, and 100 parts of sub-carbonate of potash.

The density of this flint-glass is from 3·1 to 3·2.

The following composition, expressed in kilogrammes, gives the quantity necessary to fill the crucible: sand, 100 kil.; deutoxide of lead, 100 kil.; sub-carbonate of potash, 30 kil.

This composition gives a very white flint-glass, of a density of from 3·5 to 3·6, and which is perfectly suitable for opticians.

It is not necessary to use either lime or arsenic, the only effect of which would be to diminish the whiteness of the material.

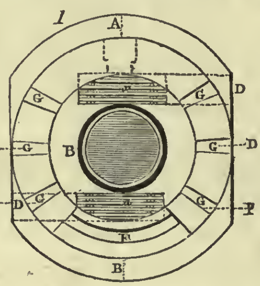
Details of the operation for flint-glass.—The crucible is to be heated in a special furnace kept for the purpose, and when at a white heat, it is to be introduced, in the usual manner, into the melting-furnace, which has been brought to the same temperature. This operation cools the furnace and the crucible. The furnace must be re-heated in order to bring it to the highest possible temperature before introducing the materials. This takes about three hours. The throat of the crucible, which has been closed with two stoppers to prevent the entrance of smoke, is then opened, and about 10 kilogrammes introduced; one hour after, about 20 kilogrammes more; then, two hours after, 40 kilogrammes. Each time the crucible must be re-closed with the greatest care, and nothing must be put in until the coal on the grate ceases to give out any smoke. At the end of from eight to ten hours, the whole of the composition will have been introduced. The crucible is left without being opened for about four hours; then the stoppers are removed for the purpose of introducing the cylinder of fire-clay, which has been heated separately to a white heat in the same furnace, and kept at that temperature until placed in the crucible; care is to be taken to keep it perfectly clean and free from ashes. At this period, the flint-glass is melted, but it still contains bubbles. Nevertheless, the bent iron bar is introduced into the cylinder, and the first stirring is given, which serves to coat the cylinder with glass, and to effect a more intimate mixture. In about three minutes, the iron bar is white-hot; it is taken out, and the ledge

of the cylinder is placed on the edge of the crucible. This cylinder, being specifically lighter than the glass, floats slightly inclined, because its upper ledge is outside of the glass. The two stoppers are so replaced as not to push the ledge of the cylinder into the glass, and the stirring up of the fire is recommenced. Five hours afterwards, a fresh stirring up with a single iron bar takes place, the glass is already well refined, and then from hour to hour there is a stirring, each time with a single iron bar; great care being taken that at each stirring there shall be no smoke in the furnace, and that the lower doors of the furnace are closed. After having thus used six iron bars, from 25 to 30 centimetres in thickness of coal is thrown on the grate, which forms a mass quickly reduced to coke, and which allows the furnace to cool, without exposing the grate uncovered. The various openings of the furnace are unclosed; the whole furnace and the crucible thus gradually and slowly cool. This operation tends to cause the bubbles which are not yet disengaged to rise to the surface. At the end of two hours this operation is finished; the furnace is again brought to the melting heat. After five hours of the highest temperature, the glass has resumed its greatest fluidity, the bubbles have disappeared, the grates are completely closed below, and the great (*brassage*) stirring commences—that is to say, as soon as one iron bar is hot, another is substituted for it, and on so for about two hours. At the end of this time the material has acquired a certain consistence, the stirring is not executed without difficulty; then the last iron bar is taken out, the cylinder is removed from the crucible, which is very carefully closed, as well as the chimneys and openings, except a small hole of two centimetres, to permit the escape of the gas, which may have remained in the fuel. When the disengagement of gas ceases, the furnace is entirely closed, and it is suffered to cool, which takes about eight days. The door of the furnace is then removed, the crucible, with its contents, taken out, usually in a single mass, except some fragments which become detached round it. The only object now is to make use of this mass and these fragments, the mode of doing which we will explain directly, after having given the details of the operation for crown-glass, which, as may be supposed, has a great analogy with the preceding.

Manufacture of crown-glass.—After many experiments, the following composition is found to be the best: white sand, 120 kil.; sub-carbonate of potash, 35 kil.; sub-carbonate of soda, 20 kil.; chalk, 15 kil.; arsenic, 1 kil.

The crucible having been placed in the furnace, as for flint-glass, the introduction of all the materials is to be completed in about eight hours, four or five hours after which the cylinder is to be introduced, and the first stirring takes place; then, every two hours, a stirring with a single iron bar; six are to be executed in this way. The furnace is to cool very slowly for two hours, after which it is to be re-heated for seven hours, this glass regaining its heat with much more difficulty than flint-glass. The great

2168.



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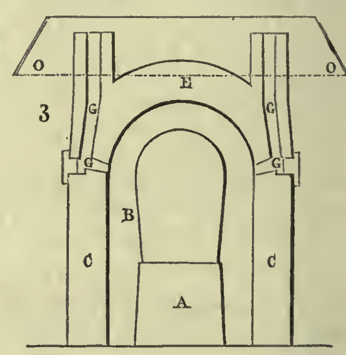

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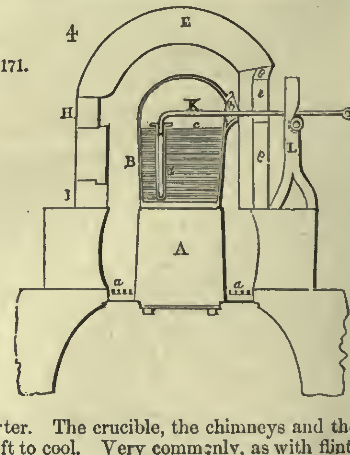


Fig. 2168. Horizontal projection of the furnace and crucible.
Fig. 2170. Section along the line E F, Fig. 2168; that is to say, along the flue.
Fig. 2169. Vertical section along the line C D of the plan.
Fig. 2171. Vertical section along the line A B of the plan

stirring then takes place, which lasts about an hour and a quarter. The crucible, the chimneys and the openings are to be closed, as for flint-glass, and the whole is left to cool. Very commonly, as with flint glass, a mass and several fragments are obtained.

Parallel faces are made on the sides of the mass, whether of flint-glass or crown-glass, in order to examine the interior, and to see how it should be divided, for it is never free from striæ, which are usually found collected in one portion of it. After this examination, it is sawed into parallel slices, or transverse sections, in accordance with the observations made. Faces are also polished on the fragments, for the purpose of examining them, and disks are made of them in accordance with their weight; for this purpose, they are first heated in a furnace, and then introduced into a muffle, where only the heat necessary to enable us to mould them is given. If the fragment is irregular, it is partially rounded by the nippers, and then, with other nippers, it is placed in a mould, under a lever press, which gives it the exact form of the mould, after which it is taken out with the nippers and carried to the annealing-arch.

The same letters mark the same objects in all the Figs. A, foundation or support of the covered crucible B. C C, walls of the furnace. D D, openings through which coal is thrown on the grate. E, arch or crown of the furnace. F, door or opening through which the crucible B is introduced and taken out; there is a small opening in this. G G G, six chimneys. H, an opening. I, hole to facilitate the placing the crucible on its support. K, bent iron bar, for working the fire-clay cylinder. L, support, with a roller across, on which the bar K is supported. M, hole, with a stopper, through which the coal is thrown. N, hole, with a stopper, through which the grate is cleared. O, hood of sheet-iron, under which the chimneys terminate. *a a*, grate of the furnace. *b*, throat of the crucible. *c*, level of the melted glass. *d*, fire-clay cylinder for stirring. *e*, opening. *f f*, bars supporting the grate. *g*, door of the opening *e*.

GLUE, is prepared from the clippings of hides, hoofs, &c. These are first washed in lime-water, and afterwards boiled and skimmed; the solution is then strained through baskets, and gently evaporated to a due consistency; then cooled in wooden moulds, cut into slices and dried upon nets. Good glue is semi-transparent, deep brown, and free from spots and clouds. When used it should be broken in pieces, and steeped for twenty-four hours in cold water, by which it softens and swells; the soaked pieces are then melted over a gentle fire, or, what is better, in a water bath, and in that state applied to the wood by a stiff brush. Glue will not harden in a freezing temperature, the stiffening depending upon the evaporation of its superfluous water. The chemical properties of glue are those of an impure *gelatine.*

The only machinery used in the manufacture are the three coppers, upon different levels, in which the skins, &c., are boiled. The uppermost copper, being acted upon by the waste heat of the chimney, provides warm water in the most economical way; the second contains the crude materials, with water for dissolving them; and the third receives the solution to be settled. The last vessel is double, with water contained between the outer and inner one, and discharges its contents by a stop-cock. The last made solution has about one five-hundredth part of alum, in powder, usually added to it, with proper agitation, after which it is left to settle for several hours.

GLYPHOGRAPHY, recently invented, is an electrotype process, enabling the artist to become the engraver of his own work. The manipulation is thus minutely described by the inventor, Palmer:

A piece of ordinary copper-plate, such as is used for engraving, is stained *black* on one side, over which is spread a very thin layer of a *white* opaque composition, resembling white wax both in its nature and appearance: this done, the plate is ready for use.

In order to draw properly on these plates, various sorts of points are used, which remove, wherever they are passed, a portion of the white composition, whereby the blackened surface of the plate is exposed, forming a striking contrast with the surrounding white ground, so that the artist sees his effect at once.

The drawing, being thus completed, is put into the hands of one who inspects it very carefully and minutely, to see that no part of the work has been damaged or filled in with dirt or dust; from thence it passes into a third person's hands, by whom it is brought in contact with a substance having a chemical attraction or affinity for the remaining portions of the composition thereon, whereby they are heightened *ad libitum.* Thus, by a careful manipulation, the *lights* of the drawing become thickened all over the plate equally, and the main difficulty is at once overcome; a little more, however, remains to be done. The depth of these non-printing parts of the block must be in some degree proportionate to their width; consequently, the larger breadths of *lights* require to be thickened on the plate to a much greater extent, in order to produce this depth. This part of the process is purely mechanical, and easily accomplished.

It is indispensably necessary that the printing surfaces of a block prepared for the press should project in such relief from the block itself as shall prevent the probability of the inking-roller touching the interstices of the same whilst passing over them. This is accomplished in wood engraving by cutting out these intervening parts, which form the lights of the print, to a sufficient depth; but in glyphography the depth of these parts is formed by the remaining portions of the white composition on the plate, analogous to the thickness or height of which must be the depth on the block, seeing that the latter is in fact (to simplify the matter) a cast, or reverse, of the former. But if this composition were spread on the plate as thickly as required for this purpose, it would be impossible for the artist to put either close, fine, or free work thereon; consequently the thinnest possible coating is put on the plate previously to the drawing being made, and the required thickness obtained ultimately as described.

The plate thus prepared is again carefully inspected through a powerful lens, and closely scrutinized, to see that it is ready for the next stage of the process, which is, to place it in a trough, and submit it to the action of a galvanic battery, by means of which copper is deposited into the indentations thereof, and, continuing to fill them up, it gradually spreads itself all over the surface of the composition, until a sufficiently thick plate of copper is obtained, which, on being separated, will be found to be a perfect cast of the drawing which formed the *clichée.*

Lastly, the metallic plate thus produced is soldered to another piece of metal to strengthen it, and then mounted on a piece of wood to bring it to the height of the printer's type. This completes the process and the glyphographic block is now ready for the press.

It should, however, have been stated previously, that if any parts of the block require to be lowered it is done with the greatest facility in the process of mounting.

One manifest advantage which glyphography has over etching and wood engraving is, that the artist makes his drawing as he intends it to appear. No reversing is necessary; the work during the progress of drawing is as immediately conspicuous as if it were done upon paper with a black-lead pencil. Compared with wood engraving, with which it comes into direct competition, it seems susceptible of more delicacy, and is not more expensive than wood engraving of approximate quality.

GOLD. (*Syn.* Anglo-Sax., *gold:* Dutch, *goud:* Germ., *gold:* Goth., *gulths:* Icel., *gull:* Dan. and Swed., *guld:* Tart., *goltz:* Pol., *zloto:* Gr., *chrysos:* Lat., *aurum:* Ital., Span., Port., *oro:* Fr., *or:* Welch, *aur:* Pers., *zuraljin:* Hind., *sonnau:* Arab., *dahaba:* Heb., Chald., Sum., *zahav.*) In its native state, this metal has never been found pure, but always alloyed with silver; and it frequently contains copper in addition. The proportion of silver is, from less than one per cent. up to an amount that renders it, more properly, an ore of silver. Copper, when present, is usually in very small quantity.

Pure gold is unalterable by atmospheric agents, and consequently, preserves its beauty and lustre indefinitely.

This fact, taken in connection with the facility of working the native metal, must have attracted the notice of man at a very early period. As a consequence, we find it spoken of in the most remote records of history.

Physical properties.—Pure gold has considerable lustre; less, however, than steel, silver, mercury, or platinum, but more than copper, tin, and lead. In masses, it has a bright yellow color, very slightly tinged with red; but when beaten into leaves exceedingly thin, it becomes translucent, and assumes a greenish tint. It was suggested by Vauquelin that its true color is blue, and that the appearance of green is due to a mixture of yellow rays, reflected from the thin leaf of gold. Buisson cites many experiments to prove that when reduced to an impalpable powder, by electricity or otherwise, the color of gold is purple. It seems, therefore, that savans have not yet been able to agree as to what is the true color of this long-known substance.

Pure gold is softer than silver, and possesses malleability and ductility in a greater degree than any other metal. It may be beaten into leaves so thin as to require 251,154 folds to make one inch in thickness. The coating of gold upon ordinary *gold lace* is yet thinner; because in making it, a small cylinder of silver is covered with 1-48th its weight of gold, and drawn into wire, which is rolled until 11·8 feet in length weigh but one grain. Reaumur covered a cylinder of silver with 1-360 its weight of gold. It was drawn into a wire of which 6 feet weighed one grain; and then rolled to a width of 1-48th of an inch, which increased its length to 7·5 feet; and yet the silver was so completely covered that the microscope failed to detect the least appearance of it.

The tenacity of gold is less than that of platinum, copper, and iron. A weight of 173·3 lbs. is sufficient to break a wire whose diameter is 0·0784 inch, or nearly 1-13th of an inch. Its tenacity is lessened by hammering; but its stiffness and elasticity are increased. The tenacity may be restored by exposing the metal to sufficient heat. A temperature barely enough for fusion renders it brittle; it must be more strongly heated to recover its ductility entirely. It also becomes brittle when suddenly cooled.

It expands upon being heated more than silver and copper, and less than iron and mercury. Whilst passing from the liquid to the solid state, it contracts more than any other metal. A volume which is 1· at a temperature of 32° F., becomes 1·00146 at 212° F.

According to Berthier, the specific gravity of gold after melting, is 19·258, which is increased to 19·367, if the metal has been much hammered. Berzelius gives 19·40 to 19·65, and other experimenters obtained results between these extremes. We are disposed to adopt 19·3 for melted gold, and from that to 19·65 for hammered gold, according to the amount of compression.

Its atomic weight is 1243·013, oxygen being unity, and 199·2 in a system where hydrogen is taken as unity.

It conducts heat more rapidly than any other metal, and is a better conductor of electricity than any other, except copper.

Chemical properties and compounds.—The chemical symbol of this metal is **Au**.

When it is heated to about 2016° F., it enters into fusion; and when completely liquid, assumes a bluish green color. It cannot be volatilized at the temperature of our hottest furnaces; but when exposed to the compound blowpipe, it is converted into vapor, which will gild a silver plate held above it. It may be also volatilized by the sun's rays, in the focus of a very powerful burning lens. In very fine powder, it becomes incandescent, at the temperature of 122° F.

Gold does not oxidate at ordinary temperatures, nor in the hottest furnaces; but a slight oxidation takes place when exposed in thin leaves to the lens, burning mirror, compound blowpipe, or a galvanic battery of ample heating power. In a vacuum, the electric spark divides it into a very minute powder.

Few of the acids act on gold singly. Nitric acid, when concentrated and boiling, exerts a feeble though sensible action. Nitrous acid also attacks it. Sulphuric acid, even if highly concentrated and boiling, produces no effect whatever. Selenic acid dissolves gold, and is converted into selenious acid. It was observed by Proust, that when in an extremely minute state of division, gold was dissolved in very small proportion, by concentrated and boiling nitric acid. Mixtures of nitric acid with hydrochloric, hydrobromic, hydriodic, and some other acids, dissolve it readily, and form chlorides, bromides, and iodides of gold. It may also be dissolved, and a chloride formed, by treating it with a mixture of 4 parts nitric acid and 1 part sal ammoniac, or any other alkaline hydrochlorate. The same result may be attained by using hydrochloric acid, mixed with any nitrate whatever.

Alkaline solutions have no action upon gold; but in the *dry way*, and at a high temperature, (though insufficient for fusion,) it has been shown by Buchner that divers oxygenated substances give out their oxygen to gold, or determine its absorption from the atmospheric air.

Tenant has proved that when nitrate of potash is heated with finely divided gold, the latter is sensibly attacked; and a combination of oxide of gold and potash is formed—a circumstance that should be borne in mind by artists who purify their gold filings by this means. The gold which combines with the alkali, may be recovered again by treating the alkaline mass with water; when the whole of the gold will be precipitated in a fine powder.

With borax, at a red heat, the color of the surface of gold is rendered lighter, but the ordinary color is restored again by heating it to redness, with either nitrate of potash or common salt. This was known to the ancients. Exposed to heat whilst covered with charcoal in powder, the surface assumes a beautiful shade of yellow; but whether by the formation of a carburet, has not yet been determined. Sulphur and selenium do not act on gold at any temperature, nor does the vapor of hydrosulphuric acid; but the alkaline persulphurets readily form sulphurets with gold, both in the humid and dry way. Phosphorus and arsenic, aided by heat, combine directly with it. Gaseous and liquid chlorine also act upon it, and the latter dissolves it readily. Iodine has no perceptible effect, further than to tarnish the surface. Hydriodic acid dissolves it.

Oxides.—The affinity of gold for oxygen is less than that of any metal. They combine in two proportions, constituting the protoxide and peroxide of gold; and there is some reason to believe, with Berzelius, in the existence of an intermediate oxide of a purple color, containing twice the amount of oxygen of the protoxide.

Protoxide of gold is obtained by mixing a cold solution of caustic potash with protochloride of gold. It has a deep green color, and soon decomposes spontaneously into metallic gold and its peroxide; which also occurs upon the application of acids, with which the protoxide never forms salts.

It consists of gold	96·13
Oxygen	3·87

Peroxide of gold may be formed in several ways; but the best mode, according to Pelletier, is to heat magnesia or oxide of zinc in slight excess, with a solution of perchloride of gold, and wash the residuary matter with nitric acid. If concentrated acid be used, we have the anhydrous peroxide; but with diluted acid, the hydrated peroxide is produced. This peroxide has a styptic, metallic taste, retains its oxygen very feebly, and forms salts only with concentrated nitric, sulphuric, and acetic acids. The addition of water to these solutions precipitates the gold, either as an oxide or in the metallic state. Peroxide of gold combines with vitreous substances in fusion, and communicates the beautiful yellow color so much admired in artificial gems and stained or colored glasses.

Although the term *peroxide* of gold is usually applied, we might perhaps more properly rank it with the acids, and designate it by the term *auric acid.* It does not form stable compounds with other acids, but, like them, combines with metallic oxides, forming a class of salts called *aurates.* The solutions of these are usually colorless, or nearly so; but may be tinged yellow by the addition of other acids. The oxygenated acids produce precipitates of hydrate or peroxide of gold, having a violet color more or less deep, or even black, according to the strength of the solutions.

The aurates of soda, potash, and baryta, are very soluble in water: the solutions are colorless, and have an alkaline reaction.

The aurate of magnesia is slightly soluble in water, but more so if chloride of magnesium be present. When solid it is easily decomposed by nitric acid, which produces very pure peroxide of gold, or its hydrate, according to the strength of the acid.

The purple powder of cassius, so much used to produce a fine purple color in artificial gems, enamels, and glass, is sometimes classed with the aurates, although it probably does not contain auric acid. Chemists are not agreed in regard to the precise nature of this valuable compound of gold, but our limits do not permit the discussion of the question here.

There are several different processes by which it can be prepared; and it varies in its tints according to the method adopted.

Buisson gives the following as the best to produce a beautiful purple color:—(*a*) Dissolve 1 part granulated tin in hydrochloric acid, avoiding an excess of the latter. (*b*) Dissolve 2 parts tin in a mixture of 3 parts nitric and 1 part hydrochloric acid; taking care, as before, that the solution be exactly neutral. (*c*) Make a neutral solution of 7 parts gold in a mixture of 1 part nitric and 6 parts hydrochloric acid. Dilute the last solution with a large quantity of water, and mix it with the deutochloride of tin (*b*), and then add the solution of protochloride (*a*), drop by drop, until the precipitate shall assume the desired purple color. An excess of the protochloride (*a*) changes the color of the powder to brown, and an excess of the deutochloride (*b*) gives it a violet tint. As soon as the desired color is attained, the liquid should be decanted, and the precipitate washed to prevent further change in its color. It retains water when heated to 212° F.

Its composition, according to Buisson, is,

Gold	28·5
Deutoxide of tin	65·9
Chlorine	5·2

The chlorine in this specimen might all have been removed if it had been sufficiently washed.

Berzelius analyzed a specimen of a fine purple; which contained,

Gold	28·35
Deutoxide of tin	64·00
Water	7·65

Oberkampt found two specimens to consist of,

	Clear purple.	Violet color.
Gold	79·5	39·8
Oxide of tin	20·5	60·2

These results show wide differences in composition.

It gives a beautiful purple color to glass, which sometimes disappears by fusion, but reappears in a smoky flame. Besides this, several other colors are produced in glass by mixtures with the purple powder. With oxide of silver we have a deep crimson, and with oxide of antimony a deep brown.

Other compounds, giving a purple color to fused glass, may be formed by mixing solutions of chloride of gold with protonitrate of tin, chloride of antimony, or of bismuth, or even protosulphate of iron.

Sulphurets of gold.—There are two sulphurets, both of which are reduced to the metallic state, at a low red-heat.

The *protosulphuret* is dark brown, or nearly black; and is obtained by passing sulphuretted hydrogen gas through a *hot* solution of chloride of gold. It consists of

Gold	92·51
Sulphur	7·49

The *deutosulphuret* has at first a dark yellow color, which becomes brown when dried. It is prepared by passing sulphuretted hydrogen gas into a *cold* solution of chloride of gold, and consists of,

Gold	80·47
Sulphur	19·53

Phosphuret of gold is prepared by passing an excess of phosphuretted hydrogen gas into a solution of gold. At first the metal is precipitated, which at length combines with the phosphorus. The compound is black, without metallic lustre. It is more fusible than metallic gold itself; and, after being melted, becomes of a grayish white color, crystalline and brittle with a granular fracture.

Fulminating gold.—There are two different kinds of this compound, both of which were supposed to be aurates of ammonia; but Dumas has shown that nitrogen also exists in them.

The first has a dark gray color, and is prepared by digesting a solution of chloride of gold with ammonia, and *carefully* drying the precipitate so as to lessen the danger of explosion. At a little above 212° F. it explodes with great violence from a *slight* blow, or from friction. It consists of

Gold	77·60
Nitrogen	5·56
Ammonia	6·65
Water	11·25

The second species is of a deep yellow color, and is made by digesting the chloride of gold in a slight excess of ammonia, and drying as before. At the temperature of 212° F., when suddenly heated, it detonates most violently; but after having been very slowly heated to 266°, the temperature may be raised to 300°, and even 320°, before it will explode.

Great caution is requisite on the part of those who prepare or handle these and other fulminating compounds, and the many terrible accidents which have occurred, should warn all but experienced manipulators from meddling with them in any manner.

Chlorides.—Gold combines in two proportions with chlorine.

Protochloride of gold is prepared by cautiously evaporating a solution of the perchloride to dryness on a sand bath, and heating the residue at the temperature of melting tin (frequently stirring with a glass rod) until it ceases to give off chlorine. It forms a white saline mass, slightly tinged with yellow. It is insoluble in, nor does it color cold *water*, if free from perchloride. It is little subject to decomposition at ordinary temperatures, if secluded from the light and kept dry; but both light and heat decompose it into perchloride and metallic gold; and boiling water very promptly does the same.

It consists of Gold	91·51
Chlorine	8·49

Perchloride of gold may be obtained by dissolving pure gold in thin leaves or fine powder, in a mixture of 1 part (by measure) pure nitric acid with 4 parts pure hydrochloric acid, and cautiously evaporating the excess of acid. It is soluble in water, and the solution is yellow; but becomes pale if there be an excess of acid. It is decomposed by degrees, if exposed to light; and, at a red-heat, the chlorine is driven off, leaving the gold. It consists of

Gold	65·18
Chlorine	34·82

Metallic gold is precipitated from its solution by phosphorus, and most of the metals and the salts of iron. The salts of tin in solution produce purple precipitate. If gold be precipitated by means of a solution of caustic potash in alcohol, we obtain it in an extremely minute state of division, suited for painting, for gold inks, and other purposes.

The solution of this perchloride in ether is used for gilding the surfaces of iron and steel; the durability of which is increased by previously immersing the article for one or two minutes in a solution of silver or copper, so as to cover it with a thin pellicle of either of these metals. The gilded surface must then be well burnished.

Perchloride of gold unites with most of the metals to form compounds called double chlorides, which our limits will not permit us to notice.

Bromide of gold, when dried, has a blackish color, without metallic lustre. It dissolves readily in water, and gives to it a deep red color; which is also that of the crystals produced from the solution.

It consists of	Gold	46·8
	Bromine	53·2

Iodide of gold is insoluble in cold water, and slightly soluble at 212° F. It has a greenish yellow color, and consists of

Gold	34·5
Iodine	65·5

Alloys of gold.—When 12 parts *manganese* and 88 parts gold are melted together, an alloy is produced, having a pale yellowish gray color, with considerable lustre and hardness, and little ductility. Its fracture is granular and spongy. It is less easily fusible than gold, and the manganese may be completely separated by roasting.

Iron and gold have a strong affinity for each other, and the latter may be united in all proportions with steel or cast-iron. Gold may be used for soldering iron. An alloy with 8 per cent. of iron is of a pale yellowish gray color, very ductile and tenacious, and harder than gold. With from 15 to 20 per cent. of iron, the alloy is gray, and will take a very beautiful polish. It is used in jewelry under the name of gray gold. When 75 to 80 per cent. of iron is alloyed with gold, it has the color of silver, and is so hard as to be applicable to the purposes of cutting instruments.

Cobalt readily unites with gold, and forms alloys of a dull yellow color, which are brittle when the proportion of cobalt is 1-60th.

Nickel and gold have a brass yellow color, and are also brittle.

Copper has a great affinity for gold, and combines in all proportions. It heightens the color of gold, and incréases its hardness, whilst its ductility is somewhat impaired. The maximum hardness is attained with 1-18th copper. These alloys being more fusible than gold, are used for soldering this metal.

The alloy called *jewellers' gold* should contain at least 74·6 of gold. In France, according to Berthier, it varies from 92 to 25 per cent. In Great Britain, 18 carats or 75 per cent. is the standard for jewellers' gold; although the proportion of this metal is rarely so much. In Sweden, it is 76·6 per cent., it being there, as in most parts of Europe, regulated by law. In the United States, the standard of gold is not subjected to any legal provision, except in regard to coin, which must contain 9 parts gold to 1 alloy; of which alloy, at least one half must be silver. In Great Britain, the coin consists of 11 parts gold and 1 copper; and in France, 10 parts of gold and 1 part of copper.

In order to deepen the color of gold alloyed with silver, artists have a mode of alloying a small portion of copper with the surface only, which is done in the following manner: 1 oz. of yellow wax is melted, and there is added to it a mixture of 2 oz. calcined alum, 12 oz. red chalk, 2 oz. verdigris, and 2 oz. peroxide of copper, (copper scales.) The four last named must be ground to an impalpable powder, completely mixed with the melted wax, and moulded into sticks for use. After the surface of the gold is well rubbed over with these sticks, the article must be exposed to heat sufficient to burn off the wax entirely. It is then burnished, and washed with a liquor composed of one pint of water to 2 oz. ashes produced by calcining argal or crude tartar, 2 oz. common salt, and 4 oz. sulphur.

Antimony unites easily with gold, and produces alloys of a color more or less pale, according to the proportions used. They are brittle, and have a dull granular fracture. The presence of a very minute proportion of antimony destroys the ductility of gold. It was from this faculty to render brittle, which antimony exerts over all the other metals, that the earlier chemists gave it the title of *regulus*, or *little king*. To its sulphuret was given the name of *lupus metallorum*, because, in the purification of gold, its feeble affinity allowed it to yield the sulphur to the inferior metals, while itself combined with the gold. The sulphuret is still used for the same purpose.

Tin forms with gold compounds more fusible than the latter; they are ductile when cold, but crumble at a red heat, if the proportion of tin be as much as 1-37th. With 1-12th tin the alloy is of a pale yellow color, but slightly ductile, and has an earthy fracture.

Zinc, in small proportion, renders gold brittle; even its vapors sensibly produce this effect on gold in fusion. With 1-10th zinc the alloy is very brittle, and has the color of brass. With $\frac{1}{2}$ zinc it is white, very hard, and takes a high polish. Hellat asserts that an alloy of seven parts zinc and one part of gold is entirely volatilized in a furnace.

Bismuth forms with gold brittle alloys of a brassy color. The vapor of bismuth is also sufficient to diminish the ductility of gold.

Lead forms alloys with gold which are brittle in every proportion. It requires but one part of lead in 500,000 of gold to alter sensibly its ductility. An alloy consisting of one part lead and twelve parts gold is extremely brittle, and has a dull granular fracture similar to that of porcelain.

Silver and gold may be united by rapid fusion in all proportions; but if the fused mass be very slowly cooled, part of the silver, in combination with a small proportion of gold, separates and floats upon the surface, leaving beneath an alloy of five parts gold and one part silver. The alloys of these metals are more fusible than gold, and have a greenish tinge; even 5 per cent. of silver produces a decided change of color. The proportions used for the *green gold* of the jewellers are 70·8 of gold, and 29·2 of silver. These alloys are very ductile, and are harder, more elastic, and more sonorous than either of the metals themselves. The maximum hardness is attained when the proportion of silver is one-third.

Platinum may be united with gold in all proportions; but to produce an alloy completely homogeneous, it should be exposed to a very high temperature, so as to effect a perfect fusion. These alloys

are ductile and elastic. When they contain from 7 to 10 per cent. of platinum the color is dull yellow like tarnished silver. With 1-5th it exactly resembles platinum; with 1-17th platinum it is in appearance not distinguishable from gold.

Platinum and silver together combine with gold in all proportions, forming double alloys which are ductile, and possess more stiffness and elasticity than alloys of gold and silver only. Platinum is sometimes introduced into an alloy of silver, gold, and copper, called *doré*, and it is not easy to detect the fraud.

Palladium and gold form alloys with less ductility than that of the pure metals. They have a granular structure, and vary in color from white to gray. With equal parts it is nearly white, and a very small proportion lessens the color of gold.

Rhodium and gold form alloys, according to Del Rio, which are brittle, unless the proportion of the former be very small, when it hardens the gold without impairing its ductility. With 1-7th rhodium the color is unaltered—a striking difference between its effects and those of platinum and palladium upon gold.

Iridium, in being alloyed with gold, but slightly affects its color, and produces ductile alloys.

Osmium also forms ductile alloys with gold.

Arseniurets of gold (as alloys of arsenic with gold are termed) may be formed by exposing heated gold to the vapor of arsenic. The gold absorbs a very small proportion, but retains it with so strong an affinity that it cannot be entirely separated even at a very high temperature. This alloy is brittle.

Tellurium may be combined with gold artificially, by treating the latter in solution with telluretted hydrogen gas. The native combinations of these metals found in Transylvania will be noticed among the ores of gold.

Mercury and gold form alloys called *amalgams*. They may be formed by immersing or agitating gold in mercury, which dissolves it even at common temperatures; but the combination is hastened by heat. An alloy saturated with gold and compressed in chamois skin is white, and at first soft, but soon becomes solid. It crystallizes in four-sided prisms, and contains two parts of gold and one of mercury. When sufficiently soft to be kneaded between the fingers, it contains six or seven parts mercury and one of gold. Amalgams are used in *gilding*, (q. v.)

Mineralogical Occurrence of Gold.

1. Native metallic gold.
2. Gold containing rhodium.
3. Gold with silver and tellurium.
4. Gold with silver, tellurium, and lead.
5. The same as the last, with the addition of antimony.
6. Gold in iron and copper pyrites and Galena, usually in very small proportion.

1. *Native metallic gold.*—It is in this state that nearly all the gold obtained by man is found; but, as has been already stated, never entirely apart from other metals. It varies in color from gold yellow to brass yellow, grayish and greenish yellow, depending upon the nature and proportion of the metals with which it is alloyed.

It occurs in grains, scales, threads, and plates, and also in masses from a few grains in weight to several ounces; and in a few rare instances lumps have been found weighing many pounds. It also occurs in small crystals having the form of the cube, or its derivatives.

Its specific gravity varies according to the proportion of other metals with which it is alloyed, and is much less than would be calculated from that of the pure metals.

Boussingault and others have endeavored to show that the silver contained in native gold is united in definite proportions. We think, however, this view is altogether untenable, in the face of the fact that the numerous analyses which have been made show that the silver in native gold exists in all proportions, from less than one per cent. and upwards, until it constitutes more than half the weight of the native alloy.

The following table gives the composition of specimens from the principal gold regions now worked in various parts of the world.

	LOCALITY.	GOLD.	SILVER.	SPECIFIC GRAVITY.	ANALYST.
1	Schabrowski, Siberia..............(copper ·35)	98·96	0·16		Rose.
2	Saxony	96·90	2·00		Lampadius.
3	Upper California	95·70	not stated.		U. S. Mint.
4	Scharlausch, Siberia ....*	95·00	4·80		Rose.
5	Boruschka, " ....*	94·40	4·80	17·060	"
6	Brazil ....(0·15 platinum)	94·00	5·85		D'Arcet.
7	Bellembugeush, Siberia	93·50	6·40		Rose.
8	Peros Pawlosk, "	92·60	7·10		"
9	Upper California	92·10	not stated.		U. S. Mint.
10	Kuslinski, Siberia	91·90	8·00		Rose.
11	Ufaley, " ....*	91·40	8·50		"
12	Upper California	92·10	not stated.		U. S. Mint.
13	" " loss in melting 0·38	90·70	8·80		Rivot, Paris.
14	" "	90·50	8·80		U. S. Mint.
15	Kurchwa, Siberia ....*	90·30	9·60		Rose.
16	Czarwo Nuolajewesk, Siberia	89·40	10·00	17·480	"

	LOCALITY.	GOLD.	SILVER.	SPECIFIC GRAVITY.	ANALYST.
17	Besolk, Siberia	88·70	11·30		Rose.
18	Malposo, New Grenada	88.58	11·42		Boussingault.
19	Upper California	88·50	not stated.		U. S. Mint.
20	Llano, New Grenada	88·24	11·76	147·06	Boussingault.
21	Baja, "	88·15	11·85		"
22	Rio Sucio, "	87·94	12·06	14·690	"
23	Upper California	87·50	not stated.		U. S. Mint.
24	Gasuschka, Siberia *	87·30	12·30		Rose.
25	Petro Powlowsk *	86·50	13·20	16·870	"
26	Burburu, Transylvania	85·10	14·70		Boussingault.
27	Ojas, New Grenada	84·50	15·50		"
28	Boruschka, Siberia	83·90	16·10	17·060	Rose.
29	Trinidad, New Grenada	82·40	17·60		Boussingault.
30	Upper California	81·20	not stated.		U. S. Mint.
31	African gold *dust* (11·80 copper)	78·00	9·48		Thomson.
34	Titisibi, New Grenada	74·00	26·00		Boussingault.
35	Guano, "	73·68	26·32		"
36	Marmato, " in cubic and octahedral crystals in a vein of pyrites in syenite	73·45	26·55	12·666	"
37	Otromma, N. Grenada, in octahedral crystals.	73·40	26·60		"
38	Santa Rosa, "	64·93	35·07	14·149	"
39	Transylvania, in cubic crystals	64·52	35·48		"
40	Schlangenberg, Siberia	54·00	36·00		Klaproth.
41	" "	28·00	72·00		Fortia.

Those marked (*) contained traces of copper. No. 41, containing 72 per cent. of silver, would be classed more properly with native silver.

So far as is yet known the gold from California is alloyed with silver only; the oxide of iron, separated in melting, exists in the minute cavities and fissures in the scales, and adheres to the surface only. The average loss in melting is stated to be about 2½ per cent., which, as the assays were made from the *melted* metal, would somewhat reduce the per centage of gold.

Although obtained over a large extent of country, the California gold from the western slope of the Sierra Nevada has more uniformity in its composition than that of other gold regions, from which a sufficient number of specimens have been analyzed to enable us to form an opinion. This will appear from the following table giving the maximum and minimum proportions, which have been found to exist in some of the most important localities.

	Maximum.	Minimum.
California	95·70	81·20
Siberia	98·96	28·00
South America, (New Grenada, &c.)	88·58	64·93

One specimen from Siberia contained nearly 99 per cent. of gold, and ½ per cent. of silver and copper, being the purest native gold yet known.

The gold of the western slope of the Andes contains more alloy than that of Siberia or California. Of the other regions the analyses reported hitherto consist generally of a single specimen, or of so few that no deduction can be made from them.

An opinion seems to have prevailed in California, that the gold from the affluents of Feather river was purer than that from the districts further south, but the assays at the United States Mint do not confirm this opinion; on the contrary, they show that the average rate of purity seems about equal throughout the region. The usual range after melting is from 87·5 to 90·5 per cent. of pure gold. The general average is between 88·5 and 89· per cent. If, therefore, the value of the silver be added, it would appear that the average value of the gold from California differs little from the standard for the gold coin of the United States.

3, 4, and 5. *Telluric ores of gold.*—In the metalliferous districts of Transylvania a considerable amount of gold is obtained from ores consisting of combinations of tellurium with several other metals. The following indicates the composition of the most important of these:

	Sp. gravity.	Gold.	Silver.	Copper.	Antimony.	Lead.	Sulphur.	Tellurium.	Observer.
1	5·723	30·00	10·00					60·	Klaproth.
2	10·678	26·75	8·50			19·50	0·50	44·75	"
3	8·918	9·00	0·50	1·30		54·00	3·	32·20	"
4		7·50		1·		46·00	2·50	26·40	Brandes.
5	6·840	6·70		1·30	4·50	63·10	11·70	13·	Berthier.

The first variety crystallizes in small rhomboidal prisms. It is soft, with an irregular fracture, and of the color of steel.

The second is white, tinged with yellow. In some cases it is in lamellæ, but appears granular in others, and crystallizes in four-sided rectangular prisms and in small lamellæ.

The third has a deep leaden-gray color, approaching that of specular oxide of iron, with a very shining lustre. It is soft, slightly flexible, has a lamellated structure, and crystallizes in hexagonal plates slightly elongated.

The fourth closely resembles in appearance the third, from which it differs little in composition.

Although the fifth differed little in external appearance from the two last, it will be observed that in the relative proportions of its constituents there is a considerable variation.

6. *Gold in iron and copper pyrites, and in galena.*—The native sulphuret of iron so generally contains traces of gold as to occasion the remark by Gahn, that it was rare to meet with a specimen of this mineral from which gold was entirely absent. The same may also be said, in a great measure, of the native sulphurets of copper and iron, or copper pyrites, and the sulphuret of lead, or galena, although it is probable that it does not so uniformly apply to the two latter, and especially the last.

Geological distribution of gold, and its localities.—With the exception of iron, (and possibly copper,) it may safely be asserted that the geological districts within which gold occurs embrace a larger aggregate area than those of any other metal. And yet the proportion of gold to that of the substances from which it must be separated for the use of mankind is so *extremely* minute, that the cost of eliminating it must necessarily be such as to maintain a very high commercial value for this metal in all future times.

Native gold occurs in veins which intersect hypogene or igneous, as well as metamorphic rocks; but the veins in the former have hitherto almost always proved too poor in metal to be worked with profit, unless in connection with other metals.

Among the metamorphic rocks, especially in talcose slates, we find the auriferous veins most numerous as well as most productive. And although the veins in porphyries, trap, and other hypogene rocks, usually are much less rich in metal than the slates, yet the veins in these are little productive, or do not contain gold at all, where these rocks occupy extensive areas without intrusive rocks forced up between or around them.

These conclusions are sustained by the fact of this being the geological structure of all the districts in the world known to contain gold, under circumstances that permit it to be extensively availed of for the uses of mankind.

The gold-bearing veins usually consist of quartz, of a texture so firm and hard as to require a large expenditure in mining it, compared with the value of the metal obtained; more especially when it is worked to considerable depths below the surface, where atmospheric agents have not impaired the solidity and firmness of the vein-stone.

These, like all true veins, are generally inclined at a considerable angle from the plane of the horizon, and are often vertical, or nearly so. In thickness they vary considerably; the same vein is sometimes contracted to a width of an inch or less, whilst at other points it is expanded in thickness to many yards They extend downwards to greater depths than the miner has ever reached.

The gold occurs sometimes disseminated throughout portions of the vein in minute scales, often so small as to be invisible to the naked eye; then again it is found in scales, plates, or amorphous masses, varying in size from the smallest visible dimensions to those having considerable weight. These are sometimes irregularly distributed throughout the vein-stone, but most commonly extend within parts of the vein, or upon its sides. Small crystals of gold also occur in the cavities of the vein-stone. Iron pyrites usually accompanies native gold, and sometimes also copper pyrites, both containing some gold disseminated within them, and not chemically combined.

By far the larger proportion of gold hitherto has been procured from the deposits of diluvium and alluvium, in the valleys and ravines which have been formed in those regions where metallic veins existed prior to the formation of such valleys and ravines.

The gold in these transported deposits (or *drift*, as they may be termed) formerly existed in those portions of the veins destroyed by the operations of nature producing these denudations, and which often result in the formation of glens, ravines, and narrow valleys. This destruction and re-formation are incessantly going on; but during the present geological period with less energy than in that earlier era called the *drift period* by geologists. Now, as then, carbonic acid and oxygen, aided by heat and water, are the chief agents by which the rocks and stony matters are disintegrated. The currents of water in hilly and mountainous districts have usually considerable rates of descent, so as readily to float off the more finely-divided portions in sand and mud, as well as to remove the larger gravel and boulders.

The only substances possessing specific gravities too great to be moved far from whence they were liberated, are the heavier metals and some of their oxides. The weight of gold is such that it is rarely transported far from the veins. It is true, that when in minute scales or powder, part of it is carried off during floods, by adhering to the passing sands, but it is rarely deposited in available quantities, except in close proximity to the veins in which it existed.

Notwithstanding the apparently large quantity of gold hitherto procured in the drift matters, from the most remote periods, we may safely assume that it bears an infinitely small proportion to what yet remains imprisoned within the rocks at no greater distance from the surface than has already been reached by the industrious miner in other researches. The small amount of space occupied by the ravines and valleys of *excavation* in metalliferous regions, compared with that remaining below and between them, clearly proves the correctness of this opinion. But those who found hopes of wealth upon gold mining should not, because of the existence of these vast stores, suppose that the mining of them must of course be advantageous; on the contrary, the sad experience of the world has almost always shown exactly the reverse.

The principal cause of this result is the enormous cost of blasting and removing the hard, intractable vein-stone which, in most instances, embraces the gold, and this, too, in narrow, confined places under ground. Even after this is brought out of the mine there are additional expenses of large amount

incurred in machinery, labor, and materials for reducing it to powder, and separating the gold with the aid of mercury. When the mine is pursued to a considerable distance below the surface, there is a heavy additional expense incurred in keeping it free from water, as well as in bringing up the mined materials.

After all this is done the miner finds, in most cases, the proportion of gold is too small to pay the expenses; and yet the allurements of gold mining are such as often to cause the parties to persist until they are ruined, whilst they are each day expecting a brilliant result.

At the present time a few veins are said to be worked in Virginia, and other parts of the gold region of our Atlantic slope, with reasonable profit.

In Peru and Chili gold is rarely obtained in this manner; indeed, the unproductiveness of the auriferous veins in that region has given rise to a common saying there, that "to work a gold mine is certain ruin;" and they add, "a silver mine is altogether uncertain, whilst a copper mine is certain gain."

In Siberia the veins are rarely worked with advantage, and almost the whole amount of gold obtained in that country is procured from the drift.

Nature, in the latter case, does the mining, leaving it for man to separate the metal mixed with and covered by the sedimentary matters. As these deposits are of moderate thickness, they are liable to be soon exhausted of their gold when extensively worked. This has frequently occurred where the proportion of metal was enough to pay the cost of working, as in Europe, in Asia, (except Siberia,) and in most parts of South America, Mexico, and the Atlantic slope of the United States. It is but a short time since the Siberian gold attracted attention, and being very extensively deposited, it still continues productive.

Gold has been collected upon the western slope of the coast range of mountains in Upper California for more than 40 years; but previous to the spring of 1848 it was not known to exist upon the Sierra Nevada. The numerous false representations and romances, published in reference to the gold of that region, and to the facility of gathering it, brings to mind the excitement that was produced more than three hundred years ago by the abundance of gold which Pizarro and his fellow-brigands obtained in their marauding expedition to Peru, by robbing the unoffending natives.

From all the knowledge we can gather at this day, it would appear that the narrow and deep ravines in Upper Peru must have been rich in gold, and yet all worth working out, which had not been collected by the natives, was soon exhausted by their conquerors, who made slaves of the conquered, and compelled them to dig and wash for the metal. Much of it had been collected and was in possession of the Incas and their subjects, as may be inferred from the statement of the quantity offered as a ransom by the ill-used captive Inca, Atalhuapa; which was to fill with gold the room in which he was confined to a mark on the wall as high as a man could reach. In a very short time his part of the contract was nearly completed, when his cruel captors divided the spoils and put the Inca to death. When melted up the amount was found to be equal in effective value to about nine millions of our dollars. With all this apparent abundance of gold at the time of the conquest, the supplies imported into Spain soon dwindled; and but for the discovery of certain veins extremely rich in silver, the importance of Peru in reference to the precious metals would have declined at a much more rapid rate than actually happened.

Pieces of gold weighing more than a few ounces have rarely been met with in nature, yet some of considerable size have been recorded. The largest piece hitherto known was found in the drift near La Paz, in Peru, in the year 1730, and weighed a little more than 59 lbs. Troy. It was not uniform in composition, and the different parts varied in the proportion of gold from 75 to 95·8 per cent. Next in size was found in Sonora, Mexico, a lump weighing 48·6 lbs. In Siberia, according to Humboldt, pieces have been found also of large size; the largest weighed 27 lbs., and is in the Imperial Museum. Others were found weighing as follows: 26·25 lbs., 16·64 lbs., 20 lbs., 14·25 lbs., and 11 lbs. Troy. One piece weighing 28 lbs. was found in 1828 at Reid's mines, Cabarras county, North Carolina, and another also weighing 13 lbs.

It was often asserted in newspapers during the year 1849 that large masses of gold had been picked up in California; 28 pound lumps were often reported, probably because one of that weight had been found elsewhere, but no well-authenticated weight had been found as late as October, 1849, exceeding 81 oz., or 6·75 lbs. Troy. More recently the newspapers in New York state the receipt of a lump in this city, weighing 13 lbs. The largest yet received at the mint of the United States is the one above noticed, weighing 6·75 lbs.

The similarity in geological structure of the chief gold regions is such that we may with reasonable certainty expect its occurrence wherever this structure exists; or, in other words, wherever there are extensive formations of talcose slates, accompanied to a greater or less extent by intrusive rocks. For instance, Tyson, more than twelve years since, announced in the Transactions of the Maryland Academy of Science, that the talcose slates of Maryland would be found to contain gold; and within two years past it has been found in Montgomery county, and may be expected in the other counties to the northeastward. A few years later, Dana, when with the Exploring Expedition in California and Oregon, noticed that the formations justified the expectation of the existence of gold, as has been since realized. The principal gold region begins on the north, just about the southern limit of Mr. Dana's opportunities of observation, because the party travelled along the Sacramento valley southward of Mount Shasty.

It lies upon the western slope of the Sierra Nevada, which is a plain rising from the eastern edge of the Sacramento valley to the summit of the Sierra, with an elevation of about 8000 feet in from 50 to 70 miles.

The chief rivers, rising near the summit, form almost torrents, with average rates of descent, of from 100 to 180 feet to the mile. The deep ravines which have been furrowed out by the flowing waters have others opening into them, which have also their affluents so numerous that the whole flank is everywhere intersected by glens and ravines, and presents the appearance of being composed through

out of isolated conical peaks, each rising higher upon approaching the summit of the Sierra; above the ordinary height of which there are several very elevated volcanic peaks.

This flank from the valley upwards, to no great distance from the summit, is composed of argillite, talcose, chloritix, and hornblende slates, with intrusive masses consisting of trap, porphyry, syenite, serpentine, and other igneous rocks, which have been protruded through the slates in many places. This constitutes the gold region (the main one) of California.

The outcrops of veins of quartz are very numerous throughout the district, and many of them, without doubt, contain gold; but as late as October, 1849, none had been fully opened, except at one spot on the Mariposa river, an affluent to the southern part of the San Joaquin.

It is from the abundance of the fragments of quartz, which form these outcrops, and which are often spread to a considerable width on each side of the vein, that the popular notion has arisen of "a vast superstratum of *quartz rock*, containing veins of gold, resting upon a substratum of talcose slates," and which has nearly supplanted a former fancy equally incorrect; that of "the gold having been scattered over the country by volcanic action."

The rapidity with which the slate rocks are disintegrated, from the causes before noticed, and the finely divided state into which they are resolved, causes them to be carried off with great facility by the annual floods even in the present day; but during the greater inundations of the *drift periods* the scouring out of ravines must have been much more rapidly effected. The result, however, up to the present time, has been to form innumerable ravines, mostly having very steep declivities and of every depth, from those of small size up to that of the north branch of the American river, which has in some places worn its bed down at least 3500 feet below the adjacent highlands.

It is very probable that the rocks which once existed in the spaces now constituting the ravines, and which have been broken up and removed to form them, formerly made up at least one-tenth of the whole mass of the metalliferous district, within 1000 feet of the surface of the sloping highlands.

The quartz being the principal vein-stone, and resisting the action of atmospheric causes, is little subject to disintegration. It is, however, liable to be separated into fragments, such as are commonly known as *flint-stones*, and which are found of all sizes in irregular angular fragments on and near the surface of the ground, wherever veins or beds of this stone occur in the rocks beneath. Examples of these are common in most parts of the world, and are familiar to every one in the region between the great tertiary and cretaceous district of the Atlantic slope of the United States, and the eastern limits of the mountains.

Whilst the metamorphic rocks are readily crumbled down and washed off by the waters, but few of these fragments of quartz are carried off, other than those that chance to fall into ravines, through which rapid streams of water flow; consequently, they continue to accumulate and extend upon the surface.

This great amount of denudation may be considered practically, a natural mining operation upon a most extensive scale. Nature has thus liberated the gold and left it among the drift in the ravines and small valleys. The metal most abounds in the inferior parts of the drift, for the reason that during former periods of greater inundations every thing of greater specific gravity than the heavier metals was driven through and out of these ravines by the force of the waters. As the strength of these floods became less the larger boulders were left, and finally those of smaller size and gravel and sand.

It was conjectured by many who have not attended to geological pursuits, that this metal, whose weight is so many times heavier than water, or even stony substances, had been *washed* from an Eldorado at the summit of the Sierra Nevada; and many a gold-seeker searched as diligently for this fancied spot as did the Spaniards in Peru, who thought 300 years ago it was near the summit of the Andes. The weight of gold is such that whilst its gravitating force lends aid to the waters in forcing it down the steep hill-sides into the ravines, it is amply sufficient to resist all currents which ever prevail along them. This conclusion is fully confirmed by not finding gold, of any moment, in the drift, out of the regions in which the auriferous veins occur, or at a distance from them. Such is the fact on the affluents to the Sacramento and San Joaquin rivers from the Sierra Nevada; corresponding also with what has been observed in every other gold region in the world. It is, however, possible that the pulverized portions of the metal were carried away to a small extent, adhering to the passing sands, as before said.

An impression seems to prevail in this country that the drift in which the gold of California is found is mainly sand, but this is rarely the case in California or elsewhere, except, perhaps, with the minute scales from Africa, called *gold-dust*, which name is most inappropriately applied by many to the scales and small pieces from California; where the drift of the gold region mainly consists of gravel and coarse sand, filling the interstices between boulders, many of which are of large size. The beds of the ravines are usually very narrow, and the drift resting upon them is from 2 or 3 to 16 feet deep. In some places the bottom of a ravine expands in width, and the lessened velocity of the waters over these during high freshets permits the deposit of sand, but these do not usually contain so large a proportion of gold as an equal area of the bed of the narrow ravines.

The seemingly large amount of gold obtained in some of the ravines in California is to be attributed to many causes, that may be briefly noticed.

1. The main gold region extends along the western flank of the Sierra Nevada a distance exceeding 500 miles, with a mean width of perhaps 35 miles. There is reason to believe that scarcely any ravine of importance within this extent has escaped the probing operations of the gold-seekers. It was, however, chiefly upon the portion between the parallels of 36° and 40°, that the great army of operators spread themselves during the year 1849. The area of this portion of the district is nearly 10,000 square miles, and it is believed that within it the drift has been probed to the bottom almost everywhere upon the beds of the ravines in search of *rich diggings*. The gold-digger is very rarely satisfied at any spot, and is almost incessantly changing his location and digging holes in hopes of finding one of the rich

spots that are often *reported*, but rarely found. By this means the best places for working are soon found, and their treasures rapidly exhausted.

2. The existence of the gold was first ascertained in February, 1848; and the official letter of Gov Mason stated the number working in July of that year amounted to 4000. In the year following an immigration amounting to 100,000 persons took place; and as the larger portion could find no other means of support, they were compelled to occupy themselves at the gold-diggings. It is clear, therefore, that the operatives in this way within the first two years greatly exceeded the numbers that ever flocked to any other auriferous district before known, in so short a period.

3. The gold liberated from the veins by the natural causes before noticed, has readily found its way into the beds of the ravines. Their declivities are usually very steep, and they are narrow, especially those of great length, and through which large bodies of water flow during the seasons of rains and melting snows. The gold that formerly existed in the veins, within the space now occupied by these ravines, has been left under and beside the streams which flow perennially through some of them, and during part of the year through others.

It is apparent almost, but might be shown by calculation, that amounts greatly larger than seem to have been procured from the drift of any of these ravines, might have been deposited without there having been a single vein containing a workable proportion of metal. A considerable quantity, it is true, has been gathered from some localities, but upon calculating the solid contents of a vein which once extended across any of those enormous ravines, we shall learn how small an average proportion of gold in the vein-stone may leave a large deposit of metal. Take, as one of medium size in that region, a ravine of 1000 feet deep, and whose acclivities are 30°, and we shall find, if we assume the vein to have been only one yard thick, the destroyed portion would equal nearly 200,000 cubic yards, weighing more than 4500 pounds per cubic yard. If it contained, at a mean, gold to the value of one cent only in a pound of the vein-stone, this single vein should have left near it in this one ravine, gold to the value of nine millions of dollars. And yet auriferous veins are very numerous in that region, so that gold occurs in the drift of almost every one of the ravines, which everywhere intersect the district.

From what has now been said, it is manifest that the circumstances under which the gold in the drift was found in these gorges and ravines, have allowed it to be collected more readily than if it had been mixed with the sedimentary deposits of wide valleys, where the proportion of gold must always be small. The sudden occupation of them by a vast crowd of operators might have been expected to produce a large amount in the aggregate; but to the parties themselves it has been far less than they were led to expect, from the many false statements which have been continually published. The results in Peru and Chili, where the gold occurred under circumstances closely resembling those in California, must be expected in the latter country, and within a much shorter period.

The present irregular and unartistical mode of operating in California must, in a great measure, soon cease of necessity. But upon a reduction of the price of labor in that country, systematic modes of procuring the gold will be practised by skilful persons, under whose directions these deposits will be worked over again, yielding perhaps more gold than was obtained at first.

The mode of calculation we have given demonstrates the absurdity of the statements so widely circulated of the existence of vast "rock formations of quartz containing gold to the value of $2 50 to $3 00 per pound of the rock," as this *vein-stone* has been improperly termed. It is quite possible that single specimens may have yielded these proportions, but such isolated instances should not be considered as representing an average productiveness of a vein, which cannot be ascertained until after working it to a considerable extent. They vary greatly in their course, so that a vein must either be worked for many years from one point, or in numerous places, before any one can safely or prudently state its average yield.

A vein has been opened on the Mariposa river, an affluent to the San Joaquin, which is said, from good authority, to present better prospects than usual.

In Brazil native gold is obtained in moderate amount from a recently formed conglomerate, called there *Cascalho*, in which diamonds also occur.

Chili and Peru have been already referred to. Ecuador and New Grenada contain also portions of the extensive gold region of the Andes.

Nearly all the principal mining districts of the world occasionally produce gold in some proportion, (usually very small,) whilst being worked for silver, copper, lead, and other metals.

In Hungary and Transylvania a considerable amount is obtained; and it is in the latter country that the tellurets of gold occur, which were noticed among the ores of gold. It also exists in connection with silver and copper in many of the mines of Mexico and South America. The mines of Saxony, and of the Hartz mountains, produce a small quantity of this metal. It also occurs as native gold at Wicklow, in Ireland, and in minute proportion in the lead ores of North Wales. Spain was celebrated for its gold mines of former days, but produces a very little at present. Recently a gold region has been discovered in Australia, which is represented in accounts from that country to be promising. In the old-settled countries of Southern Asia and its larger islands, gold was procured in remote ages. They produce very little in the present day.

A vein of quartz with gold was mined in France some years, in the valley of Oysans, but finally abandoned, because of its poverty. Gold is occasionally collected in the eastern part of that country, near a few streams.

Piedmont contains gold mines, some of which are still worked. Veins containing auriferous sulphuret of iron are worked at Macugnana, near Monte Rosa.

More than 20 years ago quite a gold fever was produced in the United States by the finding of this metal in the northwestern part of Georgia. It was traced in a northeasterly direction into South and North Carolina, and finally through Virginia into Maryland. The ravines being of moderate dimensions, it did not require a long time to exhaust the most productive, and the veins are not extensively worked.

The geological structure of this gold region of the Atlantic slope is similar, in great measure, to that of California and other districts producing gold. Talcose slates are the prevailing rocks which, where they extend into Maryland and Pennsylvania, are less interrupted by intrusive rocks, and as far as appears are less metalliferous than those southwestward.

In addition to the large pieces before noticed, that were found in this region, many others of smaller size have also been procured from the sedimentary deposits. At this time it is impossible to form a correct opinion as to which of the two districts contain the richest veins, notwithstanding all that has been said of California, where ravines have been scoured out to an enormous depth. Those in the Atlantic gold region bear but small proportion in size to the former. It is therefore quite possible that those of California may have received their supply of gold from veins not richer in metal than those of our Southern States. It is very probable that the average depth of the ravines in the main gold region in California is ten times greater than those in the Atlantic district, and if so, should contain a quantity of gold in the same proportion, provided the veins be equally rich in each case. This mode of investigating the industrial importance of gold regions should not be overlooked by those interested in the subject.

It has been recently announced that gold has been discovered in the talcose slates of Pennsylvania, and a few years since it was found in Canada.

The list of localities might be much extended, but those already given are sufficient to illustrate our former observation in reference to the extensive distribution of gold upon the earth.

Extraction, separation, and assaying of gold.—When gold occurs native in sedimentary deposits, whose component parts are not held together by a cement, as in the cascalho of Brazil, there is required at first but a small outlay of capital for collecting it, and the fact that individuals can operate independently of each other, has usually caused a great rush of gold-seekers to every newly discovered locality of this kind. These busy themselves in hunting out and digging holes in the drift to find rich places, which are first worked, and at last these independent operators abandon the half-worked and the poorer spots, to such as apply science, skill, and combinations of labor and machinery, enabling them to obtain the metal from deposits too poor to reward the others. Such has been the case elsewhere, and similar results must necessarily follow in California at no distant period.

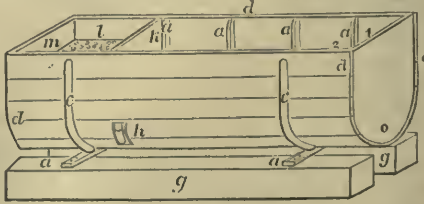
The most simple means used for separating gold from the drift matters, after they have been dug up, is to pick out the boulders and larger gravel, and wash the remaining gravel and sand with water in a suitable pan or vessel. The pan in most common use is of thick tin-plate, about fifteen inches in diameter at the top, and four inches deep, with sides inclined about 30° from the perpendicular. About one quart of the materials is taken at a time, with a suitable proportion of water; and a rotatory motion is given to the pan sufficient to throw out the sand, whilst the gold remains in it, water being added from time to time. If any gravel remain in the pan, it is picked out. The gold remaining is usually mixed with ferruginous grains, and is collected and dried. A very common mode of separating the gold from these grains is, by blowing the latter out after being dried, which occasions a considerable loss in the minute scales of gold. When, as is often the case, these grains consist of magnetic oxide of iron, they may all be gotten rid of; but when, as sometimes happens, the specular oxide or chromiferous iron are present, they cannot be removed in this way, because the magnet does not attract either of them. The pan, in skilful hands, is convenient for the more locomotive part of the gold-diggers, or those who work alone. These often also make use of small cradles or rockers, which can be transported upon mules or horses.

The simplest form of the rocker is a quadrangular box, open at the top, and from three to eight, or even ten, feet long, and ten to eighteen inches wide as well as high. At one end, which is slightly elevated, there is a coarse sieve placed at the top to separate the gravel. Several small strips of wood or iron are nailed across the bottom to check the too rapid motion of the solid matter towards the lower end of the machine, so as to permit all the fine scales of gold to subside.

In using the rocker, the materials to be washed are thrown on the sieve, and water supplied by hand or otherwise. A rapid rocking motion is now given, and the water escaping at the lower end carries off the sand and earth, leaving the gold in the rocker with the ferruginous grains. These ordinary rockers can hardly be considered an improvement upon the pan-washing; and, in fact, any mode is defective in which *mercury* is not used to separate the ferruginous grains without loss of the precious metal. This may be used in any rocker made of or lined with iron in such manner as completely to prevent the escape of the mercury.

The rocker in common use at the gold mines in Virginia is the only one that seems completely adapted to the purpose, and is equally well suited for operating upon gold in sand and gravel, or upon vein-stones reduced sufficiently fine for washing and amalgamating. It is made of large size, and effectually prevents all loss of either gold or mercury. The sieves are of cast-iron, with holes of proper size. This machine has been introduced into California, and found very effective.

2172.



The subjoined drawings represent the improved rocker.

Fig. 2172 is a perspective view.

Fig. 2173 is a longitudinal section through the axis of the machine.

Fig. 2174 shows a cross section at *h k*.

a, Ribs of strong oak, about two inches square.

d, Staves screwed to the ribs, so as (with the ends) to form a tight box, with a semi-cylindrical bottom.

c, Cast-iron supports, upon which the box rests.

a', Cast-iron plates secured by spikes or screw-bolts to the two pieces of timber *g*. There are elliptical holes in these plates, bevelled on the upper surface, so as to receive the lower termina-

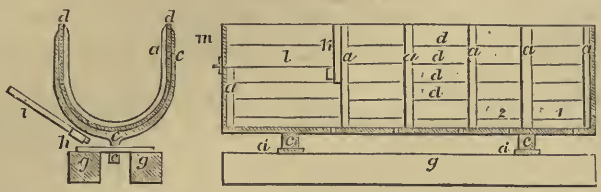
pieces of the supports *c*, and permits a rocking motion to be given to the machine by raising and depressing the handle *i*, which fits into the socket *h*.

l, A perforated plate of cast-iron, with holes one-half or three-quarters of an inch in diameter, so as to permit the passage of sand and small gravel. The retained gravel and stones are thrown out after each charge has been washed. To facilitate this, a gate is placed at *m*, which may be attached by means of hinges, or may slide in grooves at the sides.

k, A partition reaching from the top of the box to a little below the perforated plate *l*. Its use is to prevent the escape of the water and earthy matters, which are thrown on the sieve or perforated plate. The machine is then briskly rocked, by alternately raising and depressing the handle *i*, until the water, which is constantly supplied, passes through the small opening *o*, clear, or nearly so.

The small openings shown in Fig. 2173 in the bottom of the box are closed with plugs, whilst the

2174. 2173.



operation is going on, and when the gold (or amalgam, if mercury be used) is to be taken out, the plugs may be cautiously drawn out, so as to permit the water between the ribs to escape without losing the precious metal.

The box may be of wood, but for permanent locations, it should be constructed of very thick sheet-iron, or, rather, thin boiler-plate.

Native gold in veins of quartz is usually more or less mixed with iron pyrites, and sometimes with pyritous copper. The ore, after being picked over by hand, is reduced to a coarse powder in a stamping, or other mill, and agitated in a rocker with mercury, whilst the earthy matters are washed off with water. In the north of Italy, principally at Macugnagna and Vinzone, there are many factories for the separation of gold from an auriferous pyrites. The pyrites is crushed in horizontal mills to the size of a pea, and then ground with mercury and water for twenty-four hours. These ores contain only from 0·00001 to 0·0005 of gold.

In all cases where mercury is used in separating the gold from impurities, the amalgam should be pressed in a chamois skin or buckskin, which separates a portion of the mercury. What remains in the skin is distilled in an iron retort and the mercury condensed in a receiver. The gold is left as a spongy mass, which is melted to drive off any minute portion of mercury that may have remained after distillation. If silver be present in the ore, it will be found alloyed with the gold.

It is unnecessary to describe in this article the processes for separating gold contained in the various silver ores which are principally worked for that metal. In these the gold is obtained alloyed with silver and other metals; and the means of effecting it will be described at length in the article Silver (q. v.); under which also the means of separating gold from galena will be noticed, because it is similar precisely to those made use of in operating upon argentiferous galena. In fact, silver always exists in these ores.

Upon this branch of the subject it remains to treat of the means of determining the presence of gold as it occurs in nature, and in what proportion to the accompanying foreign matters. There are numerous ways of effecting this; but we shall only notice one very simple method, which, at the same time, gives the most accurate results.

This is by the use of a glass tube, about one foot long, closed at one end, and whose internal diameter, is three-fourths or seven-eighths of an inch, not too large to be stopped with the thumb. This may be about one-half or one-third filled with the auriferous sand or powdered vein-stone, and a few grains of mercury, and a little water added; after which the tube is to be well shaken for some time, so that all the gold may be dissolved by the mercury. Water is then repeatedly poured in and out, whilst the tube is inclined and gently shaken, in order to get rid of the sand. The gold, if any be present, will have formed an amalgam with the mercury; the latter may be driven off by heating over the fire in an iron spoon, or any other convenient iron utensil.

In assaying an auriferous pyrites in this manner, more accurate results are obtained if the pyrites be previously roasted and reduced to a fine powder, although most of the gold may be obtained without the roasting.

These tubes may be graduated so as to show the proportion to the bushel, or any other measure, they will contain when filled to a proper height. One whose internal diameter is ·806 of an inch (rather more than $\frac{13}{16}$ of an inch) would contain $\frac{1}{700}$ of a bushel when filled with material to the height of six inches Two such tubes, with a very small iron bottle containing mercury and a small delicate spring-balance of little cost, and to weigh not more than three to five grains, may be secured in a wooden case, and furnish a very portable, convenient, and accurate means of determining the proportion of gold in sedimentary deposits or in vein-stones, if the means of powdering the latter be accessible.

The separation of gold and silver from other metals will be more fully treated of under the head of Silver; but we shall indicate briefly in this place the most efficient and accurate means of separating gold from native alloys, as well as those artificial compounds usually met with.

Goldsmiths and other artists, in order to purify their filings and other matters containing gold alloyed or mixed therewith, frequently do nothing more than melt it in contact with nitrate of potash, (saltpetre;) but when it is desired to bring the gold nearly to purity, it is fused in a crucible, and then from two to

four parts sulphuret of antimony (the *lupus metallorum*) *gradually* added. Sometimes it is necessary to fuse the gold several times, in order to separate all other metals completely. Even silver may be thus separated from gold. But, to get rid of the antimony, it must now be fused with nitrate of potash, which completely separates it. Although we can thus procure gold in a very pure state, there is apt to be a little loss; and if silver be present with other metals, it is an expensive process to recover the silver from the mixed sulphurets which are formed.

The separation of gold from silver is completely effected either by means of *pure* nitric acid or nitro-muriatic acid, according to the relative proportions of these metals in the alloy. If the metal contains less than fifteen per cent. of silver, all the gold may be obtained in solution as chloride of gold. When the proportion of silver exceeds 80 per cent., all the silver may be dissolved out by nitric acid, leaving the gold unacted upon; its quantity may then be determined by weighing. If, however, great accuracy be desired, it should be dissolved in nitromuriatic acid, and to the *neutral* solution, protosulphate of iron added, which will precipitate the gold in a state of purity.

Alloys of gold, containing between fifteen and eighty per cent. of silver, should be fused with three times their weight of lead, and the fused mass treated with nitric acid in sufficient quantity to dissolve out all the metals likely to be present, except the gold. This fusion may be effected readily in a porcelain crucible over an Argand spirit-lamp. If, however, platinum be present, there should be added to the solution of gold in nitromuriatic acid, chloride of potassium, which will precipitate the platinum as a double chloride. The gold may then be precipitated by protosulphate of iron in a state of purity as before directed.

Jewellers often judge approximative of the proportion of alloy in gold, by means of the touchstone. Stones of several kinds are used for this purpose, but pieces of polished trap or basalt are preferred.

A number of small bars or needles (not less than ten) are prepared of gold, having known proportions of alloy. A mark or trace is made upon the surface of the stone with a piece of gold for assay; upon this trace a drop of nitric acid is placed; the same is done with the try-needles successively. The proportion of gold is inferred to be the same as in that needle whose trace on the stone is similarly affected by nitric acid.

Those who are skilled in the use of the blowpipe can readily detect with it the most minute proportions of gold, silver, and other metals in ores or alloys; and in the cases of gold, silver, and copper even the per centage of the metal may be ascertained with considerable accuracy, although the quantity operated upon does not exceed one grain.

The method of using this important instrument, and applying it to the detection of metals, will be given under the title of METALLURGY, (q. v.)

It is common to express the proportion of gold in an alloy by the words *fineness.* Thus, in the language of assayers, when they say 18 carats fine, or 750 thousands fine, they mean that 18 parts out of 24, or 750 in 1000, consist of pure gold. The method of stating the fineness of gold by carats has been discarded at the Mint of the United States, and at some of those in Europe.

The subjoined table gives the equivalents of carats in decimal parts, unity being twenty-four carats:

Carats.	Decimals.	Carats.	Decimals.	Carats.	Decimals.
1	0·042	9	0·375	17	0·707
2	0 083	10	0·417	18	0·750
3	0·125	11	0·459	19	0·792
4	0·167	12	0·500	20	0·833
5	0·208	13	0·542	21	0·875
6	0·250	14	0·583	22	0·917
7	0·292	15	0·625	23	0·958
8	0·333	16	0·666	24	1·000

Uses of gold.—The use of gold in coin, and the various applications of it to ornamental and useful purposes in the arts and in domestic economy, will come in necessarily under appropriate titles. Here will be noticed only its medicinal employment.

Preparations of this metal have been used in medicine for a long time, and were thought more efficacious in former times than in the present day, when mercury seems in great measure to have supplanted its use. Occasionally, however, it is revived upon the publication of new experiments. It is yet retained in pharmacopœias, but is little regarded by the medical profession. The compounds of this metal used in medicine are the following:

Chloride of gold, in doses of	$\frac{1}{16}$ to $\frac{1}{10}$	of a grain.
Iodide " "	$\frac{1}{16}$ to $\frac{1}{12}$	"
Cyanide " "	$\frac{1}{12}$ to $\frac{1}{10}$	"
Oxide " "	$\frac{1}{4}$ to 1	grain.
Purple powder of cassius	$\frac{1}{16}$ to $\frac{1}{12}$	of a grain.

Metallic gold in powder, precipitated by protosulphate of iron, $\frac{1}{4}$ to 1 grain.

All the above, except the oxide and metallic gold, are poisonous if several grains be administered at a dose. The Homœopathic physicians also use preparations of gold in the infinitely small doses prescribed by their system.

Annual supplies of gold.—Professor Ansted, of London, made, in 1848 an estimate of the supplies

of this metal from all sources, at the beginning of this century, which appears quite reliable, and which reduced from pounds sterling to dollars, is presented in nearest round numbers as follows. Of course minute accuracy cannot be expected in such a table.

	Dollars.
Europe	900,000
Northern Asia	370,000
Mexico	1,200,000
New Grenada	3,250,000
Peru	530,000
Potosi and provinces east of the Andes, excluding Brazil	350,000
Chili	2,000,000
Brazil	4,750,000
Total	13,350,000

The same authority has furnished the following, showing the anticipated supply in 1849.

	Dollars.
Europe, excluding Russia	968,000
Siberia	19,360,000
Asia, excluding Siberia	2,420,000
Africa	1,936,000
North America	968,000
South America	5,808,000
Total	31,460,000

The actual supply probably exceeds this estimate; for the amount from California before the close of that year is not included.

It will be noticed that, in less than fifty years, the annual supply from America fell off about 27 per cent. There has been an increase in Europe, and a considerable trade in gold from Africa, which had ceased to export this metal fifty years since. Notwithstanding the falling off from South America, the aggregate supply had increased nearly two hundred and forty per cent., mainly owing to the product of gold-washing in the Ural and in Siberia. The supplies from this source began, for the Ural, in 1819, when gold to the value of 437,000 dollars was produced, and they have steadily increased to the present time, when it may be estimated at little short of twenty millions of dollars. The average from the Russian possessions for 28 years to 1846 inclusive, is 5,540,000 dollars, but the product of the year 1846 was greater than the whole amount for the 10 years from its beginning in 1819 to 1829, (the epoch of the discovery in Siberia,) viz. 18,702,750 dollars.

Statement of Gold of Domestic production, deposited at the Mint and Branches and Assay Office at New York, from 1804 *to the end of* 1855.

Year.	*Gold.*
1804–1827,	$110,000 00
1828–1837,	5,063,500 00
1838–1847,	7,635,075 00
1848,	896,675 00
1849,	7,079,144 00
1850,	36,938,314 00
1851,	56,540,612 00
1852,	54,506,963 00
1853,	55,622,051 00
1854,	57,258,158 23
1855,	49,351,779 11
	$331,002,271 34
Deduct re-deposits of 1854,	8,041,137 00
Actual amount to 1855,	$322,961,134 34

Of this aggregate, about ninety-four per cent. has been produced by California, namely:

From California, (eight years,)		$313,235,502 77
" North Carolina,	$8,282,152 85	
" Georgia,	6,488,632 86	
" Virginia,	1,458,210 50	
" South Carolina,	1,154,305 44	
" Alabama,	192,205 92	
" Tennessee,	80,193 00	
" New Mexico,	45,937 00	
" Other sources,	64,831 00	
		17,776,768 57
		$331,002,271 34
Deduct re-deposits of 1854,		8,041,137 00
Net product of the States,		$322,961,134 34

Since 1855, and to September 1, 1857, there has been received from California as follows

Year.	*Gold.*
1856,	$40,319,929 00
1857,	25,000,000 00

Estimate of the quantity of gold raised in the provinces of New South Wales and Victoria during the period from May, 1851, *to the 31st December*, 1852.

	Ounces.	*Value at 77s. per oz.*
Victoria,	4,000,000	£15,400,000
New South Wales,	320,000	1,232,000
Totals	4,320,000	£16,632,000

GOLD-BEATING is the art of preparing what is well known under the name of *gold-leaf*, in which gold is hammered or beaten into plates, whose average thickness at the present day may be taken at $\frac{1}{250000}$ of an inch. An art which affords so remarkable a result, in rendering tangible a space which is invisible, well deserves mention here.

The extreme malleability and ductility of gold, no doubt, brought an art like this into use very soon after the metal was known, and at a very early period in the world's history. The "overlayings" which are spoken of in the Book of Exodus (chap. xxvi., &c.) were, most likely, of gold-leaf in some of the instances: at least such appears to have been the opinion of the writers of the Septuagint. The gilding of Egyptian remains, which many of us have seen, and which are, undoubtedly, of leaf in a respectable attenuation, may carry the art back to a remoter epoch even. It appears to have been no novelty to the heroes of the Trojan war, or, at least, to the Rhapsodists, who, seven and twenty centuries since, sang their deeds; and, finally, Pliny, about our era, gives particulars whereby we may judge of the state of the art, then long and extensively applied.

This author has, in this respect, been either hastily read or partly misunderstood, and thus errors of a very opposite character have crept into statements made or handed on by respectable authorities. Thus, Buonarotti, for instance, infers that the least thickness of gold-leaf the Romans could make was twenty-two times greater than ours; while Ure, apparently quoting Pliny, would make the modern gold-leaf eleven hundred times more thin. In point of fact, the reduction of Pliny's measures, will give, as the average thinness of Roman gold-leaf, $\frac{1}{78127}$ of an inch, (for he says that it is not the thinnest,) or about three times as thick as we make it now.

No account remains of the methods practised by the ancients for this purpose; but there can be little doubt that they were similar to, though with less efficient means than, our own, which are more the result of patience and skill than of science or civilization. The first notice that we have of the process dates back to the ninth century, when a German monk, Theophilus, speaks of the employment of parchment as an envelope to protect the surface, and of the use of red ochre or chalk (our workmen at this day very often call it *talc*) to prevent the leaves from sticking. Parchment, or vellum, must soon have been found too thick to answer the end perfectly; but the introduction of what is called *gold-beaters' skin*, (by the French artists, *baudruche*, and by the Germans *goldschlägerhaut*,) which is prepared from one of the membranes (the *peritoneal*) of the larger intestines (the *cæcum*) of the ox, is of uncertain date. It is affirmed by some to have been originally an Irish discovery; but the precise mode of preparation is kept as a sort of mystery by the few persons who furnish the article for gold-beaters. The general principles of the mode are, however, very well understood. The particular secret would hardly be worth the trouble of penetrating.

To manufacture gold-leaf, the metal is required in theory to be in a state of purity. All alloy is at the expense of malleability. But in practice, this is rarely, if ever, attained, and the usual fineness is that of coin, which in France and the United States is ninety per cent.; in Great Britain $91\frac{2}{3}$ per cent.; and in Bavaria, where the principal amount of gold-beating in Germany is done, $97\frac{9}{10}$ per cent. fine. In France it was stated, thirty years ago, that the most approved practice was to mix equal parts of old Spanish coin and pure gold, which would result in an average proportion of $95\frac{5}{8}$ per cent. fine. Below 75 per cent. fine, the manufacture would be, in labor and waste, a losing business.

The principal aim of alloying, when it is done of design, seems to be in the production of a variety of color—silver making the leaf pale, copper deepening the tint. These effects are more particularly noticed in the article Gold; they are similar in the leaf as in the more solid masses; only in the state of tenuity, the green and purple tinge spoken of there is more easily excited and more vividly displayed. Whatever may be the character and degree of alloy, the manipulations of the gold-beater are the same in kind, and will be now briefly described.

1. *Casting.*—The metal is placed, with a little borax to promote fusion, in a black-lead crucible, or crucibles, and set in a furnace. When perfectly melted, it is poured into cast-iron moulds, three or four inches long, three-quarters of an inch wide, and about half an inch deep, and holding each about one thousand grains of metal. These moulds are made with faces a little concave, to allow the cast to draw easily; and before pouring, they are heated, and rubbed with linseed-oil or tallow on the inside, to drive off moisture and promote an easy separation. When sufficiently cool, the ingot is taken out, and re-heated in an open fire, or a small annealing-furnace, by which it is softened, and the adhering grease driven off.

2. *Laminating.*—In older times, this was effected entirely by the hand-hammer; now a flatting-mill or laminating rolls are employed. The French still use, however, a preliminary forging upon a steel anvil, (of three inch by four inch sides,) with a hammer of about three pounds weight. The face of this hammer is about one inch and a half square, and its handle about six inches and a half. With this they bring down the thickness of the ingot to one-sixth or one-seventh of an inch. The English

perform the whole of the operation in the rolls. As the success of the work and the excellence of the leaf ultimately depend a good deal upon the uniformity of the lamination, care is taken to use a proper and accurate machine. These machines have been successively improved; until now there is little, if any thing, left to be desired. During the hardening processes of lamination and forging, if the latter be employed, the riband has to be frequently annealed, to prevent cracking. Formerly, the lamination was thought sufficient which had brought the thickness down to $\frac{1}{25}$ of an inch, with a width of one inch; and the balance was done by hand, cutting the riband into lengths of one inch and a half, piling twenty-four of the lengths evenly together, and forging them all at once till they came square. This is the practice with some of the French and German gold-beaters to this day; but others, having access to more perfect machinery, continue its application to the lamination until the thickness is brought to about $\frac{1}{700}$ of an inch. As dimensions like this cease to be appreciable, the degree of lamination is estimated by weight; and the direction usually is, to bring it down until a square inch of riband weighs six grains and a half; in this state it is ready for the *beating* proper.

3. *Beating.*—The implements and fixtures for this are, an anvil, hammers, skins, shears, parting-knives, &c. The *anvil* is a block of marble, weighing 250 or 300 pounds, or more, at pleasure, with a face of nine inches to one foot square, carefully made even and smooth. This is set in a frame wood-work, strong and solid, and upon a firm foundation. A ledge, five or six inches high, runs round three sides of the frame; to the remaining side an apron of leather is attached, which is lifted by the workman. The object of all this is to catch and retain fragments of the precious metal. The *hammers* are, ordinarily, four in number, varying in weight. Their faces are from three to five inches in diameter, and slightly convex. The weight of the first or flat hammer is about fifteen pounds; the second (which the French term the commencing-hammer) weighs from six to eight pounds; the third, or spreading-hammer, with a smaller face, and more convex, weighs about five pounds only; and the last, or finishing-hammer, is again a heavy one of ten or twelve pounds, with quite a convex face. The skins are of parchment and vellum and the intestine already spoken of, cut (the two former) into squares of about four inches, and (the last) of five inches. Besides these, there are packing-boxes, also of parchment, made on a form, and cemented together, open at two opposite ends, and in pairs, so that one will slip into the other, by which the open ends are closed. The knives are pieces of cane, set into a frame, both four-square and cruciform, with sharpened edges that divide the attenuated leaf, better than any other implement, by pressure downwards only. When the leaf becomes very thin, any other motion would drag it.

Provided with these and other tools that do not require special mention, the workman lays off the riband (which comes from the laminating, as nearly as possible, one inch in width) into lengths also of one inch. This he does with dividers or a scale, and cuts off, afterwards, with shears. This is on the supposition that the rolling has been uniform, and equal surfaces therefore should give equal weights. He then arranges these squares into piles of generally 150 pieces, interposing between each leaf a piece of the vellum before spoken of, and placing the gold-leaf as near as may be in the centre of the vellum, with their edges even. About twenty extra-vellums are placed on top and at bottom, and the pack is then of proper size to be pushed smoothly into one of the parchment envelopes, which is then in its turn pushed into its mate, and the whole thus enclosed on all four sides. The pack is then laid on the marble anvil, and beaten until the small gold-leaf is extended to the size of the vellum. It is in the judicious uniformity of direction and force of the blows that the skill of the workman is displayed. Great dexterity is, in fact, attained: the hammer is shifted from hand to hand for relief without interfering with the regularity of the stroke; and when it is recollected that the absolute effect of the average hammer with the average blow is equivalent to the steady pressure of about 2800 pounds on the square inch, there will be seen to be need for discretion in the application of such a force.

During the beating, the pack is frequently turned, so as to beat on the bottom as well as the top, (as a skilful workman will do without losing the stroke,) and also folded or rolled in the hand, to secure a proper detachment of the surfaces. It is also opened from time to time to watch the effect, and shift the leaves from the centre to the outsides, that the pressure may be uniform. When the gold has been extended to the size of the vellums, about sixteen times its original dimensions, it is taken out, cut up into four squares, repacked as before, only with gold-beaters' skin instead of vellum, and beaten over until similarly extended again. The caution of folding the pack to loosen the leaves is more necessary even now than before, and so of opening and shifting. When it has attained the size of the skins, it is removed, parted into squares again, but this time with the cane, repacked and rebeaten as before into leaves of three to three and a half inches square. It is estimated that the aggregate surface of the leaves is now 192 times larger than it was originally; and their thickness may be taken at $\frac{1}{146000}$ of an inch, which is about the average of English gold-leaf, and corresponds to an extension of about 100 square feet to the ounce. But the operation is frequently carried further by repeated beatings till an ounce is extended over 160 square feet, corresponding to a calculated thickness of $\frac{1}{234000}$ of an inch nearly. The French gold-beaters claim—and their statement of weight worked on and number of leaves produced warrants the claim—to carry it down ordinarily much further than this; and our statement at the beginning of $\frac{1}{250000}$ of an inch is, probably, even within the average result, and much within the possible limits, of malleability, if these were, without regard to expense of time and waste of metal, the only points to be reached.

The French workmen are also very precise in the number of pieces, both of leaf and of *baudruche* and vellum, which go to the packs in each of the five several steps that comprise their *beating.* As the fruit of experience, no doubt, they have ascertained the number which best suits the respective implements. The English and Germans pack in different numbers, it may be supposed with the same reason; but the principles of the operation are, in all, the same.

When the leaf is considered as finished, the last thing is, to put it in the square books, such as we see in commerce. These are made of smooth paper, frequently reddish-colored, on purpose to heighten the lustre of the gold, and well rubbed with Armenian bole, to prevent adhesion. There are two sizes

one about $4\frac{1}{4}$, the other $3\frac{3}{4}$ inches square. The pack, withdrawn from its parchment envelopes, is held by one of its angles; and, with a pair of wooden pliers, each leaf is withdrawn, and laid, aided by the breath, upon a leathern cushion, where, with the cane knives, it is parted at once or successively into four pieces, the size of the book. These pieces are then similarly transferred to the book, each between separate leaves. The book holds, very uniformly, twenty-five leaves of gold. When filled, it is pressed hard with a piece of wood of its own size, so as to bring its edges close; and with a piece of linen any projecting pieces of gold-leaf are readily wiped off. Afterwards, the books are put up in packages of a dozen ordinarily, for sale.

The French artists allow between three and four days for finishing four ounces of gold. They estimate the loss in trimmings, waste leaves, &c., at fifty per cent., and consider the remaining two ounces poids de marc, ($964\frac{6}{10}$ grains English,) as yielding 12,600 leaves of the smallest size; but there is no authentic experiment of weighings and measurings in this respect.

The *parchment* employed is used as it comes from the manufacturer, only cutting out of the sheets those parts, of suitable size, which are softest and of most uniform thickness.

The *vellum*, which is procured of the finest and softest, is not further treated than by well washing it in cold water, drying it in the air under a press, and then powdering it with finely calcined and reduced selenite. Whether the implement used for this has any special influence will not be affirmed or denied; but the uniform practice, in France at least, is to use a *hare's-foot.*

The preparation of *gold-beaters' skin*, from the colon of the ox, has been already spoken of as a secret endeavored to be maintained by the few who furnish the article. Whatever their processes may be, the *gold-beater* is accustomed to test and treat it still further for himself. Thus, he first *sweats* it, by placing it between a fold of foolscap; making a pile of many pieces, he treats it to a hearty hammering until it ceases to give out any grease to the paper. Next, he moistens it with an infusion of nutmeg, cinnamon, or other spicy aromatics, with the view of preserving it, dries it in the air, moistens again as often as he sees fit, and finally dries and presses it for use. Since the introduction of *creosote*, this (as well as may be judged from the odor of some recent skins) has been applied, and no doubt more effectually.

After the skins have served some time, (some seventy or eighty beatings, for instance,) they become inspissated, or wiry, or both, and no longer allow the proper extension of the gold. This may be cured by laying them a half day between leaves of paper wetted with Rhenish or Moselle wine, or even vinegar and water. When thoroughly moistened, they are placed between layers of parchment, enveloped and beaten until dry. This beating frequently takes a whole day. They are then powdered with selenite, and fit for use.

While yet fresh, the skin is very liable to be affected by moisture which it absorbs from the atmosphere. They must be, therefore, always dried before using, which in France is done by heat in a screw-press. Care is taken not to desiccate too much, which withers and causes it to crack under the hammer.

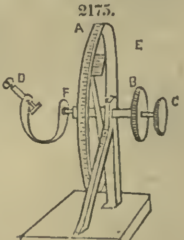
The methods which have been described here are also applicable in their measure to silver, copper, and platinum.

A sort of gold-leaf, called *party gold-leaf*, is sometimes used, made with a combination of gold and silver. Separate leaves are taken of these metals, the silver being about three times as thick as the gold, heated and laminated together, so as to produce an alloy or welding of their surfaces. The resulting party-colored riband is then beaten as if it were all of gold. Its extensibility is, of course, not so great.

There is another false gold-leaf, which is better known as *Dutch gold-leaf.* It is, in fact, a riband of brass, wash-gilded, (see GILDING,) sheared into leaves, and then beaten in the manner, and with more or less of the precautions, that have been described. When new, it is difficult to be distinguished from true gold-leaf; but it is soon tarnished by the air, and is unfit for any gilding that is not to be varnished.

GONIOMETER. (Gr. γωνια, *angle*, and μετρον, measure.) An instrument for measuring angles, and more particularly the angles formed by the faces of crystals. The instrument, chiefly used by mineralogists, was invented by Dr. Wollaston. It consists of a brass circle graduated on the edge, and furnished with a vernier, by which the divisions may be read correct to a minute. The circle moves in a vertical plane, and is supported on a stand. The axis of the circle is a hollow tube, within which is a smaller axis, fitting so tightly that when turned round it carries the other axis, and consequently the wheel, along with it, unless the latter is purposely prevented from moving. The interior axis is furnished with a milled head *a*, and the exterior with a milled head *b*; so that when the head *a* is held and *b* turned, the circle may be moved independently of the smaller axis; and when *b* is held and *a* turned, the smaller axis may be turned independently of the circle. Attached to the end of the smaller axis is a sort of universal joint, capable of being fixed in different positions by means of screws. The crystal to be examined is attached to the joint at *c* by a little soft wax, and placed so that its edge shall be parallel to the axis of motion; which adjustment is obtained by placing it so that the image of some horizontal object, as the bar of a window, successively reflected from the two faces of the crystal, coincides with another horizontal line seen by direct vision. When this adjustment has been made, the instrument is turned till the horizontal object is seen reflected from one of the faces. The smaller axis is then held fast, and the other turned till the index of the vernier points to the zero of the graduated limb. The circle is then turned round, along with the smaller axis, till the same object is seen in the same position by reflection from the other face of the crystal; when the arc passed through by the circle is obviously the supplement of the angle formed by the two faces of the crystal. In order, however, to avoid calculation, the supplements of the angles are marked on the limb, so that the angle to be measured is read off immediately.

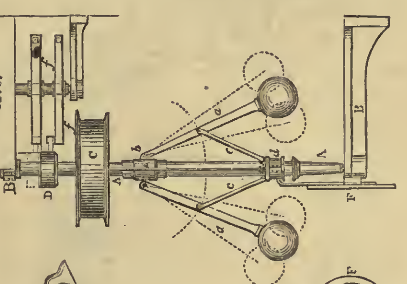
2175.

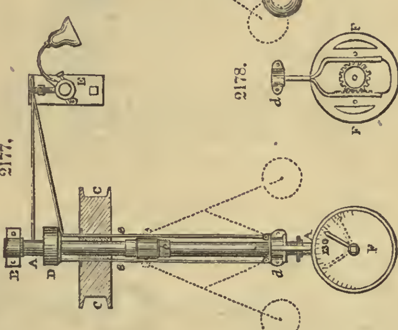


The name Goniometer is also applied to a surveying instrument, somewhat similar to a Theodolite.

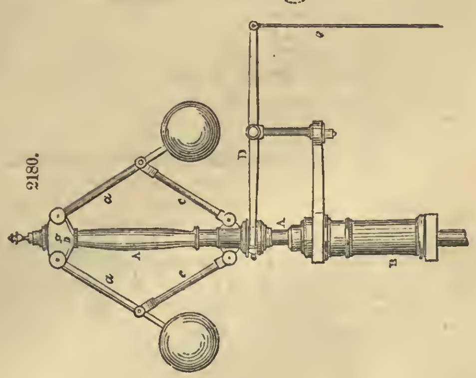
GOVERNORS. The theory of the operation of the common centrifugal governor will be found at p. 545, under the head of ENGINES. We here introduce various forms of application of the same principles, together with other contrivances to accomplish the same object. All the work required of the governor, Figs. 2176, 2177, 2178, is to ring a bell, and to indicate upon a dial the velocity of rotation o millstones.

This mechanism consists of a vertical wrought-iron axis A A, revolving in bearings B B, bolted to the wall of the mill, and carrying, towards its upper extremity, a pulley C, which receives motion from the main driving-shaft. To this axis is fixed a brass socket *b*, to which are jointed the two flat arms *a a*, terminated by the governor balls, and attached, about the middle of their length, by the two double links *c c*, to the sliding-socket *d*, made in halves and connected together by two small bolts. To this latter are also attached the two slender vertical rods *e e*, which traverse the pulley C, and convey the action of the governor to a sliding-disk D, provided with a projecting arm or catch, of such length as to come into contact, should the machinery exceed or fall short of its proper speed, with either of the two levers *f f*, which have their common centre of motion in a short vertical axis, and are attached at their opposite ends by slender wires to two sockets mounted upon a horizontal axis E; each of these sockets carries a bell, which, by the arrangement described, is rung when the catch on the disk D strikes either of the levers *f f*.


2176.


2177.

2178.


2180.

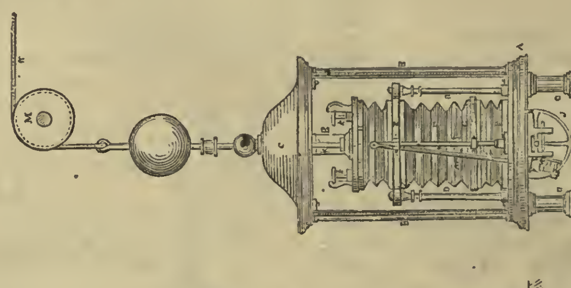
To the sliding-socket *d* is fixed a forked rod, having one of its branches formed into teeth like a rack; this rack geers with a small pinion, Fig. 2178, carrying upon its axis an index, which points out upon the graduated dial F, the speed at which the millstones are revolving. Thus, should the velocity of the prime mover relax, the vertical axis A partaking of this diminished motion, the balls collapse, the socket *d* is pressed downwards, and the rack causes the index to move from right to left. The opposite effect is produced by an increase of the speed; (these different positions being indicated by the dot lines in the figures.) At the same time the bell is sounded by the apparatus which surmounts the governor; and the attendant, by a glance at the dial, is made aware of the change in the velocity of the machinery, for which he has to compensate by altering the degree of proximity of the upper and lower stones. It is sufficiently well known to our mechanical readers that the action of the governor is in no way affected by the weight of the balls, further than that these should be made of a size proportionate to the resistance to be overcome; accordingly, in the case now before us, the work which the governor is destined to perform being very slight, the balls may be made of extreme lightness.

Fig. 2179 is an example of the original form of the governor as introduced by Watt. The distinguishing peculiarity of this form of governor consists in the connecting links *c c*, being situated *overhead*, and attached to the arms *a a*, by prolongations of the latter, which pass through a square part of the upright spindle A, to which they are both jointed by one pin. When at rest the balls are usually received into arms *g g*, curved to suit their surfaces, by which means the rods are relieved from all unnecessary strain.

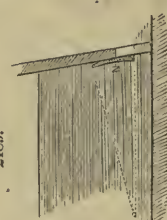
Fig. 2180 is a representation of a centrifugal governor, adapted to a small high-pressure *crank-overhead* engine. In this species of engine the governor is usually made to revolve in a short column B, cast in a piece with a forked bracket embracing the crank-shaft, and its spindle A A is driven by a pair of bevel-wheels from the crank-shaft. The spindle is surmounted by a double brass socket *b*, attached to it by means of a pin; and to this socket are jointed the arms *a a*, which, as well as the connecting links *c c*, are, in this example, finished in the lathe. The sliding brass socket *d*, to which the lower ends of the links *c c* are connected, is formed with a groove, into which is inserted the forked end of a lever D, having its centre of motion in a small wrought-iron column bolted to an arm projecting from the column B. From the opposite end of this lever depends the slender rod *e*, connecting it immediately with the throttle-valve lever, which, by this simple construction, is at once made to rise or fall, as the balls collapse or diverge in obedience to the varying speed of the engine. This is a type of the most common form of the centrifugal governor in use at the present day

Fig. 2181 is an example of a very excellent arrangement of the conical pendulum governor which is frequently adopted in highly finished engines. The peculiarity of this form consists in the connecting-rod *e*, being attached directly to the sliding-socket *d*, without the intervention of the forked lever. For this purpose the upper portion of the spindle A A is bored out truly cylindrical, to a point somewhat below the range of the sliding-socket *d*. This last is attached by means of a cotter to a small cylindrical hollow piece, which fits accurately into the interior of the spindle, and is consequently made to rise and fall with the socket *d*, a long slot being formed in the spindle to allow the cotter to traverse up and down. The lower end of the rod *e* is jointed to this interior piece by means of a swivel, so as to rise and fall with it, without being affected by its rotatory motion. At the top of the governor spindle, the rod *e* is guided in its motion by being made to pass through the small brass vase which surmounts the whole apparatus, and should it be required to be of any considerable length, the necessary rigidity may be imparted by fixing a weight to it, as shown in the figure.

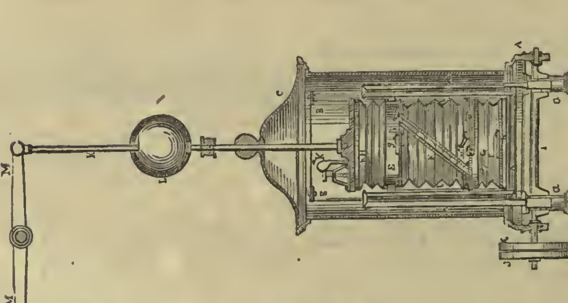
2186.



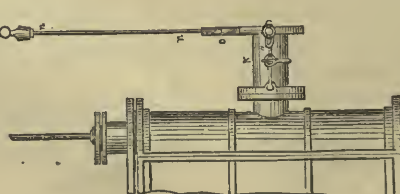
2189.



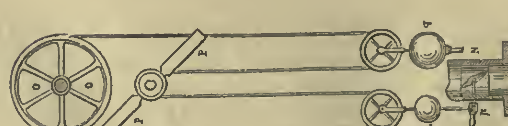
2187.



2190.



2191.



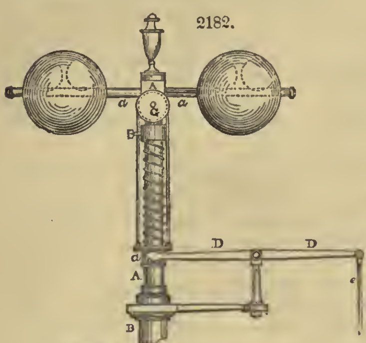
As in the example last under notice, the arms and links of this governor are finished in the lathe, as also the double cup *g*, into which the balls are received when the engine is at rest. In Fig. 2181 the

balls are shown in section, in order to exhibit the mode usually adopted for adjusting their position upon the arms *a a*.

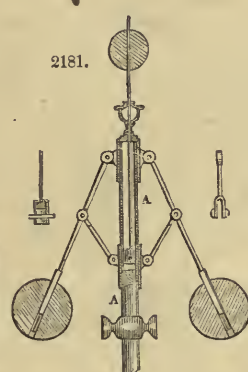
The form of governor represented by Fig. 2182 appears to be worthy of favorable consideration, on account of the principles on which it acts, and of the extreme simplicity and economy of its construction. The vertical spindle A A, which may be set in motion either by a pulley or by bevel-wheels in the usual manner, is surmounted by two equal horizontal arms *a a*, furnished with stops at their extremities. The governor balls run freely to and fro upon these arms by means of internal friction-rollers, and are drawn towards the common centre in the spindle A, by means of cords or steel ribands *i i*, passing over two pulleys at G, and attached at their lower ends to the sliding-collar *d*, in which works the forked end of the lever D D, which conveys the action of the governor to the throttle-valve. A spiral spring embracing the vertical spindle presses at its lower extremity against the sliding-collar *d*, and its pressure is regulated by a sliding-stop *h*, which can be fixed at any required elevation upon the spindle by a set screw.

The stop *h* having been set so as to cause the spring to press down the collar *d* with any approved force, and the throttle-valve opened to any required extent, the engine is set in motion. Should its speed exceed the stipulated rate, the increased centrifugal force will cause the two balls to diverge, and raising the collar *d*, will partially close the throttle-valve and diminish the supply of steam, when, the motion being checked, the spring will press down the collar and cause the balls to collapse until the desired rate of motion is obtained.

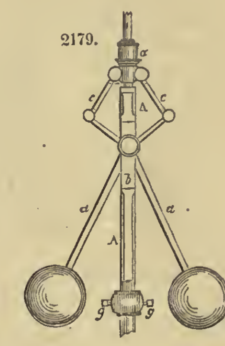
2182.



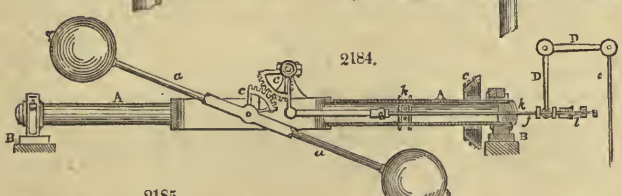
2181.



2179.

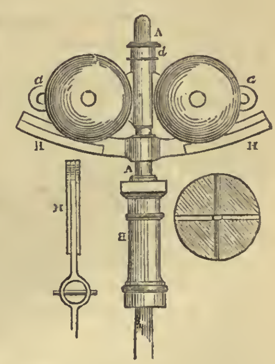


2184.



2185.

2183.



The degree of force exerted by the spring will always require to be adjusted to suit the nature of the work thrown upon the engine, because a small quantity of steam only will be required when the work is light, and a larger quantity when it is heavy, while the speed should in each case be the same, which conditions can be fulfilled with great facility and admirable precision by the use of this kind of governor.

Fig. 2183 represents a simple and compact modification of the centrifugal governor. Here the balls, instead of being suspended upon arms of a length proportioned to the velocity at which the engine is required to move, are fitted to traverse from and towards their common centre in the spindle A, upon the arms H H, which revolve with the latter, and are formed into circular arcs of a curvature determined by the same circumstances with the length of the suspending arms in the ordinary governor. By this means it is obvious that the horizontal plane of the rotation of the balls will vary with the varying speed of the engine, in precisely the same way as in the conical pendulum governor; and the vertical motion thus generated is transferred directly to the sliding-socket *d*, which commands the throttle-valve lever. For this purpose, it is necessary that each of the balls should be made in halves and riveted together with a wrought-iron pin, as shown in the section, Fig. 2183; a space being left between the hemispheres to admit of the slotted arms *a a*, which are cast in a piece with the sliding-socket *d*, and through which the connecting pins are fitted to pass freely, but without allowing any play.

The last variety of the centrifugal governor which remains to be noticed is that represented in Figs.

2184 and 2185; the former being a sectional elevation, and the latter a plan of a governor constructed by M. Bourdon, of Paris, the peculiarity of which consists in the axis of rotation being horizontal instead of vertical. The main advantage proposed to be attained by this system is the more convenient transmission of the motion of the prime mover, whether by wheel-work or by pulleys. The principle of its action is the same as that of the common governor.

The spindle A A is of cast-iron, the part to the left being hollow, while the middle portion is formed into a species of open frame-work, enclosing the principal part of the mechanism. It revolves in ordinary plummer-blocks B B, and is set in motion by the cone pulley C. The arms *a a* which carry the governor balls, are supported upon a short axis working on the points of two steel pins, screwed into the central part of the spindle and secured by jam-nuts; this axis carries also a toothed sector *c*, working into a similar sector upon another short axis to which is fixed a lever *d*; the slender connecting-rods *j j*, traversing the hollow part of the spindle, and supported by the guides *k k*, serve to convey the motion of this lever to the throttle-valve geer, which is provided with suitable arrangements for adjusting the action of the governor upon the throttle-valve.

The air-reservoir or bellows governor.—This apparatus is of French origin, a patent having been granted to the inventor, M. Molinié, of Saint-Pons, in 1838. The principle on which its action depends, consists in causing the engine to force a quantity of atmospheric air into a reservoir with a movable cover through which the air escapes, the aperture being so regulated by an adjustable valve, that it shall only escape at a given rate. Should the speed of the engine exceed or fall short of the prescribed limit, the air is forced into the reservoir faster in the one case and slower in the other than it can escape through the valve; consequently the movable cover is raised or depressed, and, by means of suitable connections, partially closes or opens the throttle-valve. The advantages proposed by this system are, first, greater regularity and steadiness of action than is attainable by the common governor, combined with equal delicacy; and, secondly, a more considerable range or amount of motion available for the purpose of regulation.

Fig. 2186 is an external elevation, Fig. 2187 a sectional elevation, (on a plane at right angles to the former,) and Fig. 2188 a sectional plan of this apparatus.

The working parts are enclosed within a cylindrical vessel, the sole being formed of a cast-iron disk A, supported upon four small columns *a a*, and the cover, of a cast-iron capital or cornice C; these are bound together by the four pilasters B B, having recesses formed on their edges for the reception of cylindrical sheet-iron panels, which thus admit of being removed at pleasure, when it is necessary to examine or repair the internal parts. In Figs. 2186 and 2187 these panels are shown partially removed.

Two small wrought-iron columns D D are also fixed to the sole-plate, and serve to support a cylindrical cast-iron vessel E, the bottom plate of which is provided with two apertures guarded by the flap-valves *d* and *g*, which open alternately for the purpose of giving admission to the air which is forced into the receiver E by the double bellows F F′; these are respectively supplied with air from the surrounding atmosphere by the apertures *b* and *f*, similarly furnished with flap-valves, the former being situated in the sole-plate A, and the latter in the movable piece G; the stream of air generated in the lower bellows passing through the upper by means of an elastic leather tube or copper pipe *c*. The cover of the fixed receiver E is formed of a movable cylindrical disk H, attached to the former by leather, in the manner of an ordinary bellows, and thereby admitting of being elevated or depressed, according to the degree of condensation of the air within the receiver; this is regulated by means of a small conical hole *h*, guarded by a pointed screw *i*, properly secured from turning, after being adjusted so that the air forced into the receiver when the engine is at its normal velocity, shall just have liberty to escape, and consequently hold the movable cover suspended. Motion is communicated to this apparatus by means of two rods *l l*, fixed to the movable intermediate piece G, and attached by means of the connecting-rods *m m* to cranks formed on the shaft I, which is set in motion by a belt from the prime mover working over the fast and loose pulleys J J. A round rod K, screwed into the movable cover H, serves to convey the motion generated by the governor to the throttle-valve or sluice-geering, as the case may be. On this rod is fixed a ball L, which, for the sake of adapting the governor to the varying circumstances in which it may be placed, is usually made hollow and partially filled with lead.

Fig. 2189 is a representation of a mode employed by M. Molinié, for rendering his governor most advantageously applicable to regulating the supply of water to a hydraulic motor. Besides the regular sluice-gate, he makes use of an additional valve N′, to which, by means of the cord and pulleys shown in Fig. 2186, he attaches the governor. The face of this valve is bent into a cylindrical form, and it is jointed by rods to a central point considerably behind the sluice-face O′. By this means the strain arising from the pressure of the water against the back of the valve is counteracted, and the action of the governor rendered sufficiently delicate.

Fig. 2190 represents the connection of this governor with the throttle-valve of a steam-engine.

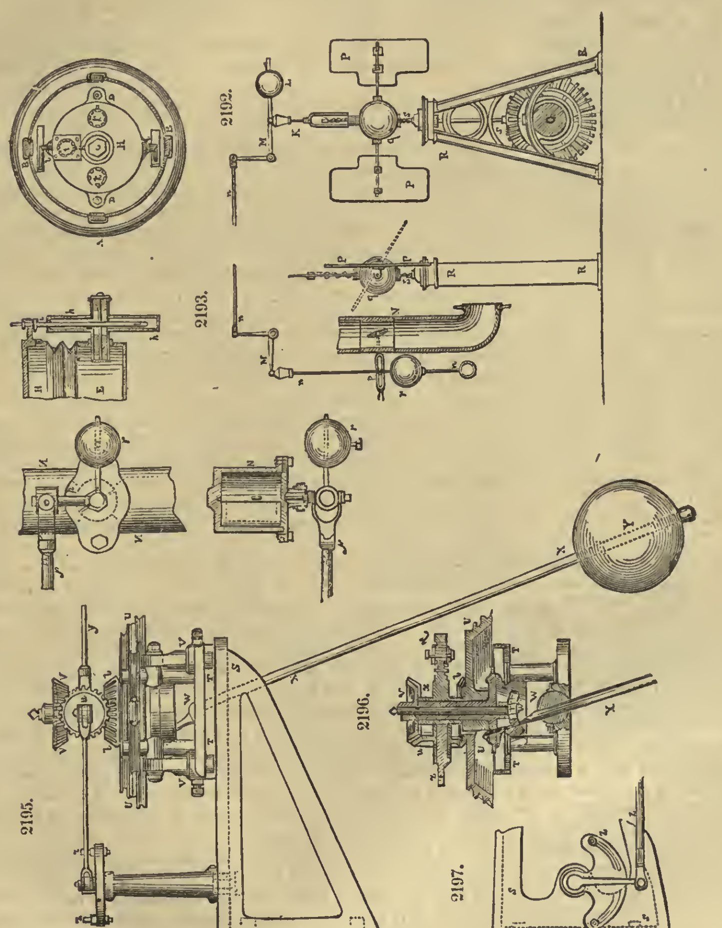
The efficient operation of this governor depends entirely on the perfection of the mechanism by which the escape of the air from the receiver E is regulated. The simple contrivance detailed is altogether inadequate, as it is neither self-adjusting nor theoretically perfect in any circumstances, as will be obvious from the consideration that the volume of any fluid escaping by a given orifice depends not only on the section of that orifice, but also on the velocity of the escape; so that the higher the velocity, the aperture remaining the same, the greater will be the volume of issuing fluid.

To compensate for this circumstance, M. Molinié has devised an arrangement at once simple and effectual. Instead of the pointed screw *i*, he makes use of a conical pin *i′*, see Fig. 2194, which is attached by nuts to the movable cover H. It is fitted to move in the interior of a brass tube *h′*, fixed to the stationary part of the air receiver, and close at the bottom, while the top is pierced with a hole of the exact size of the thick part of the pin. The air passes by an adjustable aperture into the interior of this tube; and according as the cover H is more or less elevated or depressed, the area of the aperture of escape is proportionally increased or diminished. By this ingenious contrivance, not only is the the-

oretical defect above alluded to corrected, but a great additional advantage is obtained in the more rapid and energetic action of the governor.

Figs. 2191, 2192, and 2193 represent two different modifications of the *vane governor.* The principle of its action consists in the atmospheric resistance to rapid motion being employed to counteract the force of gravity.

The form represented in Fig. 2191 is that which illustrates the principle most clearly. On the crank-shaft is fixed a drum or pulley O, and underneath it, or in any convenient situation, is placed an axis carrying a small grooved pulley, to which are attached two or more fans or vanes P P. The former communicates motion to the latter by means of an endless band or belt, which is also passed over two friction-wheels, the first of which is attached to the weighted rod *r*, which commands the throttle-valve lever *p*, and the other to a gravitating weight *q*, suspended freely on the opposite side of the axis. The area of the vanes P P, and the weight of the ball *q*, are so adjusted in relation to each other that the latter is just sufficient to drive round the resisting vanes at a certain velocity, exactly corresponding with the normal speed of the engine. Any increase of that speed, instead of accelerating the motion of the vanes, (the atmospheric resistance being nearly uniform,) tends to raise the weight and diminish the supply of steam passing through the steam-pipe N, and any relaxation of it allows the weight to descend, and thereby opens the throttle-valve in a corresponding proportion.


2188. 2192. 2193. 2194. 2195 *a*. 2195. 2196. 2197.

Figs. 2192 and 2193 are a side and end elevation of an arrangement in which this principle is carried out in a more practical and more generally applicable form. It consists of an upright spindle *s s*, supported in suitable bearings in a cast-iron standard R, placed, in the usual manner, over the crank-shaft Q of the engine, upon which is keyed a bevel-wheel, driving a pinion on the foot of the upright spindle, whereby a rapid rotatory motion is given to it. The upper part of the spindle is formed into a screw or worm, the threads of which slope at an angle of about 45°, and upon which a heavy bush or nut *q* is fitted to move easily.

This bush, which is usually formed into a ball, and corresponds in its functions with the suspended

weight q in the previous example, has attached to it two or more projecting arms furnished with vanes P P; these are so fitted upon the arms as to be capable of being set nearer to or further from the spindle, as circumstances may require; they also admit of being turned upon the arms in an oblique direction, as shown by the dotted lines in Fig. 2193, in order to diminish the atmospheric resistance. The weighted nut is connected to the throttle-valve by means of a double link and swivel K, and by levers and rods M M, $n\,n$, in the usual manner.

From the above description it will be seen that when the spindle s is driven in the direction tending to raise the nut q, the latter with its attached vanes will be carried round with it, and at the same velocity, until and so long as the resistance of the air against the vanes corresponds with the gravitating power of the weighted nut. But when the velocity of the engine, and consequently that of the spindle s, is increased beyond that point, the atmospheric resistance against the vanes will exceed the gravitating power of the nut and its mountings, and cause them to ascend upon the screwed spindle, and thus, by means of the connecting-rods and levers K L M, $n\,p$, will diminish the supply of steam passing through the steam-pipe N to the engine. If, on the other hand, the velocity of the spindle is reduced below that required by the resistance of the vanes to overcome the gravitating tendency of the nut q, the latter will then descend upon the spindle, and thereby increase the passage for the supply of steam. The speed of the engine may be permanently varied at pleasure, by adjusting the vanes upon their supporting arms, so as to increase or diminish the gravitating power of the nut to the required extent.

The chronometric governor.—This is the name given to Figs. 2195 and 2196, by its inventor, Mr. C. W. Siemens, of Berlin. The principle of its action appears to be an admirable and perfect one, involving as it does the happy idea of so combining the invariable motion of an *independent* pendulum with the varying speed of the engine or other motor, as to make the former correct *instantaneously* the fluctuations of the latter.

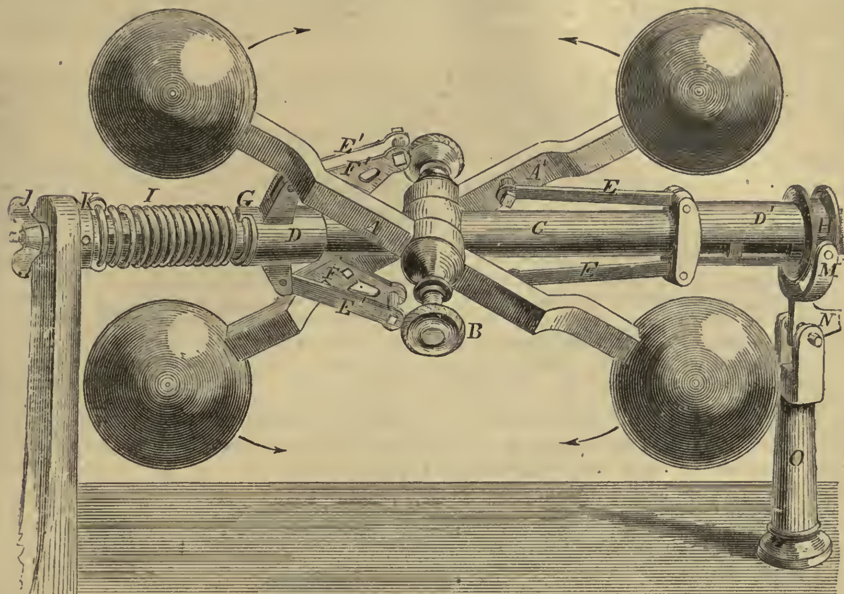
Fig. 2195 is an elevation, and Fig. 2196 a section of this apparatus, which is set upon a bracket S S bolted to the wall of the engine-house, and supported by a frame-work T T, consisting of four small columns and a circular entablature. The differential velocity between the engine and the revolving pendulum Y is obtained by means of the three bevel-wheels t, u, and v; this last is firmly connected, by an upright spindle and grooved arm w, with the upper extremity of the pendulum, produced through the ball and socket joint, which forms its point of suspension and revolution. The under wheel t is fixed to the pulley U, which is driven by the engine with its uncertain velocity, and in the contrary direction to the motion of the wheel v. Both these wheels move in geer with the third bevel-wheel u, which runs perfectly free upon its axis, and is also permitted to travel round the perpendicular socket forming the bearing of the others. It is obvious that if t and v revolve in contrary directions, but with equal velocities, the wheel u will also revolve on its axis, but will not change its angular position; while any difference in speed between t and v will cause the wheel u to follow the direction of the faster, which will at once alter the supply of steam, the arm x being attached to the throttle-valve contained within the steam-pipe N, by means of the lever and adjustable connecting-rod p and y. Another arm attached to the axis of the wheel u, on the opposite side of the perpendicular socket, is connected by means of the rod z to a lever working between two adjustable stops Z Z, which serve to confine the range of the throttle-valve within convenient limits. To maintain the motion of the pendulum a constant power is required, resembling that of the falling weight in an ordinary clock. This power is supplied by the weight r, which tends constantly to pull the wheel u to one side; and this strain being borne equally by the wheels t and v, causes the latter, and with it the pendulum Y, to revolve, while the former, revolving in the contrary direction, is constantly engaged to raise the weight back again into its proper position.

In practice it has been found that the power necessary for maintaining the action of the pendulum is much less than that required to effect the movement of the valve; and accordingly Mr. Siemens has adopted the principle of driving the pendulum with an excess of power, which shall be neutralized by friction apparatus when not wanted, and shall be allowed to act freely when the governor requires its assistance to move the valve. This is effected as follows: Surrounding the grooved arm w is situated a conical ring W, cast with the framing T T, and accurately bored out; against the interior of this "absorbing ring" a small piece of steel accurately fitted into the open end of the grooved arm w is pressed by the short end of the pendulum rod X, a spring being interposed for the purpose of letting the pressure come on gradually. It is evident that whenever there is an excess of driving weight which causes divergence in the axis of rotation, the surface of the steel rubber and of the fixed ring will be pressed together with a force exactly sufficient to balance the excess; and so soon as the pendulum falls back towards a smaller arc of rotation it will relieve the friction apparatus, and permit an increased supply of power to overcome the resistance of the valve. A second spiral spring is laid within the grooved arm w, behind the point of the pendulum, for the purpose of preventing the latter from dropping into its perpendicular position, and to facilitate its starting with the engine. The adjustment of the valve is effected at the very instant that the equilibrium between the power and load is disturbed; an advance of 1-50th of a revolution of the fly-wheel is found sufficient to close the valve entirely. By converting the friction apparatus into a regular break, the power of the governor may be increased; and in this way it may be applied for the regulation of water-wheels, and such steam-engines as are furnished with variable expansion geer, which are better regulated by increasing or diminishing the amount of expansion than by throttling the steam.

Silver's Marine Governor. A A′ are loaded arms pivoted in their centres at B, to the shaft C, which receives motion in any suitable manner from the engine. The arms A A′ are connected together through the medium of the sliding sleeves D D′, sleeve D being united to arms A A′, by means of rods E′ E′, and sleeve D′ by means of rods E E. F F′ are brackets on arms A A′, to which the ends of rods E′ E are attached. These brackets are placed at an angle of 45°, so that the line of draft of the arms and rods, when the balls fly out, is always parallel to the shaft C.

The centrifugal force of the balls is counteracted by the employment of a spiral spring I, to which the

sleeve D is attached, by means of clamps G. The tension of spring is increased or diminished at pleasure, by turning the nut J, which moves the claw collar K out or in, thus rendering the governor accordingly more or less sensitive, as desired—collar K terminates in a screw on which nut J moves.



When motion is communicated to the spindle by the engine, the balls will have a tendency to fly out in the direction of the arrows, and to move the sleeves D D′ laterally. Sleeve D′ is furnished with a collar H, which is grasped by a forked crank M, pivoted to the standard O. The lower branch of the lever N, is connected with a rod leading to the throttle valve. The connection and operation of sleeve D′ on the throttle valve, is similar to ordinary governors, and requires no particular description.

GRAPHOMETER. Fig. 2199 represents this instrument as constructed by B. Pike, Jr., Broadway, New York. The error arising from the use of an instrument, where the whole dependence is placed on the needle, being frequently influenced by local attractions, has rendered it necessary for some other method to be employed to measure angles with accuracy; among these, the common theodolite with four sights has taken the lead. It is simple in its construction, and easy in its use.

2199.

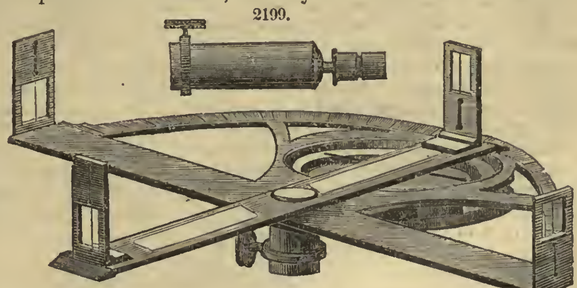


Fig. 2199 represents the graphometer, a brass plate or part of a circle about twelve inches in diameter, graduated on its edge from 0 to 180 degrees; in the opening between the moving centre and the graduated arc, is a compass about four inches in diameter; two sights are fixed on the graduated arc, one at 0 and the other at 180°. Perpendicular to the plane of the instrument, there is a movable limb attached to the limb of the arc, but a little shorter, and having the extremities slanted off, one of which forms a nonius, subdividing the degrees on the limb to minutes, and having two sights, one at each end; in each sight there is a large and a small aperture, placed alternately, the large aperture in one sight being always opposed to the narrow aperture in the other; underneath the plate is a spring to fit on the pin of a ball and socket, which fixes it the single or three-legged staff, as may be required. In the figure the ball and socket are represented detached from the instrument.

The four-sighted theodolite is the same instrument, except that the circle is entire, and the compass is placed in the centre of the circle.

GRAVITY AND GRAVITATION. These terms are often used synonymously, to denote the mutual tendency which all bodies in nature have to approach each other. See FORCE, CENTRE OF GRAVITY, and ATWOOD'S MACHINE.

GRAVITY, SPECIFIC. The specific gravity of a body is the ratio of its weight to an equal volume of some other body assumed as a conventional standard. The standard usually adopted for solids and liquids is rain, or distilled water, at a common temperature.

* Mr. Charles W. Copeland, 66 Broadway, is the general agent for the sale of this governor.

In bodies of equal magnitudes the specific gravities are directly as the weights, or as their densities. In bodies of the same specific gravities the weights will be as the magnitudes. In bodies of equal weights the specific gravities are inversely as the magnitudes. The weights of different bodies are to each other in the compound ratio of their magnitudes and specific gravities. Hence it is obvious that of the magnitude, weight, and specific gravity of a body, any two of these being given, the third may be found.

Ex. 1. The weight of a marble statue being 748 pounds avoirdupois, required the number of cubic feet, &c., which it contains, the specific gravity of marble being 2·742. Since a cubic foot of marble weighs 2742 ounces, we have, water being taken as 1000,

As 2742 : 748 × 16 : : 1 4·36 feet.

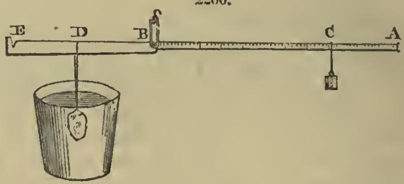
Ex. 2. Required the weight of a block of granite whose length is 63 feet, and breadth and thickness each 12 feet, the specific gravity of granite being 2·625. Here 63 × 12 × 12 = 9072 feet: then again,

As 1 : 9072 : : 2·625 : 23813900 ounces, or 664 tons 9 cwt.

A body immersed in a fluid will sink if its specific gravity be greater than that of the fluid; if it be less, the body will rise to the top, and be only partly immerged; and if the specific gravity of the body and fluid be equal, it will remain at rest in any part of the fluid in which it may be placed. When a body is heavier than a fluid it loses as much of its weight when immersed as is equal to a quantity of the fluid of the same bulk or magnitude. If the specific gravity of the fluid be greater than that of the body, then the quantity of fluid displaced by the part immerged is equal to the weight of the whole body. And hence, as the specific gravity of the fluid is to that of the body, so is the whole magnitude of the body to the part immerged. The specific gravities of equal solids are as their parts immerged in the same fluid. The specific gravities of fluids are as the weights lost by the same immerged solid.

To find the specific gravity of a body.—This may be done generally by means of the hydrostatic balance, which is contrived for the easy and exact determination of the weights of bodies, either in air or when immersed in water or other fluid, from the difference of which the specific gravity of both the solid and fluid may be computed

2200.



1. *When the body is heavier than water.*—Weigh it both out of water and in water; then say, as the weight lost in water is to the whole or absolute weight, so is the specific gravity of water to that of the body.

To do this, suspend the body by a hair to the short arm of the hydrostatic steelyard represented in Fig. 2200. Then weigh it in the air, by sliding it on this arm, until it balances any convenient weight hung at A; the long arm being graduated into any convenient number of equal parts. Then immerse the body in water, and weigh it by sliding the weight from A to C. Then as the division between A and C, is to the whole number of divisions on A B, so is unity to the specific gravity of the body with reference to the fluid in which it was immersed.

2. *When the body is lighter than water.*—In this case attach to it a piece of another body heavier than water, so that the mass compounded of the two may sink together. Weigh the denser body and the compound body separately, both out of the water and in it; and find how much each loses in the water by subtracting its weight in water from its weight in air; and subtract the less of these remainders from the greater; then use this proportion, as the last remainder is to the weight of the light body in air, so is the specific gravity of the water to the specific gravity of the body.

3. *When the specific gravity of a fluid is required.*—Take some body of known specific gravity; weigh it both in and out of the fluid, and find the loss of weight in the fluid, by taking the difference of these two; then say, as the whole or absolute weight is to the loss of weight, so is the specific gravity of the solid to the specific gravity of the fluid.

By a fortunate coincidence it happens that a cubic foot of rain-water weighs 1000 avoirdupois ounces; and, consequently, assuming this as the specific gravity of rain-water, and comparing all other bodies with this, the same numbers that express the specific gravity of bodies will denote the weight of a cubic foot of each in avoirdupois ounces.

Specific Gravities of different Bodies.

Metals.	Ounces.		Ounces.
Antimony, crude	4064	Copper, not hammered	7788
glass of	4946	the same wire-drawn	8878
molten	6702	ore of soft copper, or natural verdigris	3572
Arsenic, glass of, natural	3594	Gold, pure, of 24 carats, melted, but not hammered	19258
molten	5763	the same hammered	19362
native orpiment	5452	Parisian standard, 22 car., not ham'd.	17486
Bismuth, molten	9823	Iron, cast	7207
native	9020	bar, either hardened or not	7788
ore of, in plumes	4371	Steel, neither tempered nor hardened	7833
Brass, cast, not hammered	8396	hardened, but not tempered	7840
ditto, wire-drawn	8544	tempered and hardened	7818
cast, common	7824	ditto, not hardened	7816
Cobalt molten	7812	Iron, ore prismatic	7355
blue, glass of	2441		

	Ounces.
Iron, ore specular	5218
ditto, lenticular	5012
Lead, molten	11352
ore of, cubic	7587
ditto, horned	6072
ore of black-lead	6745
ore of white-lead	4059
ditto ditto vitreous	6558
Manganese striated	4756
Molybdena	4738
Mercury, solid or congealed	15632
fluent	13568
precipitate, red	8399
brown cinnabar	10218
red cinnabar	6902
Nickel, molten	7807
ore of, called Kupfer-nickel of Saxe	6648
Platina, crude, in grains	15602
purified, not hammered	19500
ditto hammered	20337
ditto wire-drawn	21042
ditto rolled	22069
Silver, virgin, 12 deniers, fine, not hammer'd.	10474
ditto, hammered	10511
Tin, pure	7291
ore of, red	6935
ore of, black	6901
ore of, white	6008
Tungsten	6066
Uranium	6440
Wolfram	7119
Zinc, molten	7191

Precious Stones.

Beryl, or aqua-marine oriental	3549
ditto, occidental	2723
Chrysolite of the jewellers	2782
of Brazil	2692
Crystal, pure rock	2653
Diamond	3530
Brazilian	3444
Emerald of Peru	2775
Garnet	4063
volcanic, 24 faces	2468
Girasol	4000
Hyacinth, common	3687
Jargon of Ceylon	4416
Quartz	2624 to 3750
Ruby, oriental	4283
Brazilian	3531
Sapphire, oriental	3994
of Puys	4077
Brazilian	3131
Spar, white sparkling	2595
red ditto	2438
green ditto	2704
blue ditto	2693
green and white ditto	3105
adamantine	3873
Topaz, oriental	4011
pistachio ditto	4061
Brazilian	3536
Vermilion	4230

Silicious Stones.

Agate	2620
Chalcedony, common	2616
Cornelian	2612
Flint	2594
Jade, white	2950
Jasper	2359 to 2816
Opal	2114

	Ounces.
Pearl, virgin oriental	2684
Pebble, onyx	2664
stained	2587
Prasium	2581
Sardonyx, pure	2603
Schorl, octahedral	3226
tourmalin of Ceylon	3054
antique basaltes	2923
Brazilian emerald	3156
Stone, paving	2416
cutlers'	2111
grind	2143
mill	2484

Various Stones, Earths, &c.

Alabaster, oriental white	2730
ditto semi-transparent	2762
yellow	2699
stained brown	2744
veined	2691
Amber, yellow transparent	1078
Ambergris	926
Amianthus, long	909
short	2313
Asbestos, ripe	2578
starry	3073
Basaltes from Giants' Causeway	2864
Bitumen of Judea	1104
Brick	2000
Chalk	2790
Gypsum, opaque	2168
semi-transparent	2306
Glass, green	2642
white	2892
bottle	2733
fluid	3329
Granite	2613 to 2956
Hone, white razor	2876
Lapis nephriticus	2894
Lazuli	3054
Hæmatites	4360
Calaminaris	5000
Judaicus	2500
Manati	2270
Limestone	3179
Marble	2700
Obsidian stone	2348
Peat, hard	1329
Phosphorus	1714
Porcelaine, Sevres	2146
China	2385
Porphyry	2750
Pyrites, coppery	4954
ferruginous cubic	3900
ditto, round	4101
ditto, of St. Domingo	3440
Serpentine	2500
semi-transparent, fibrous	3000
Slate, common	2672
new	2854
black-stone	2186
flesh polished	2766
Stalactite, transparent	2324
opaque	2478
Stone, pumice	915
prismatic basaltes	2722
touch	2415
common	2520
rag	2470
rotten	1981
hard paving	2460
Sulphur, native	2033

	Ounces.
Sulphur, molten	1991
Talc, black crayon	2089
yellow	2655
black	2900
white	2704

Liquors, Oils, &c.

Acid, sulphuric	1841
ditto, highly concentrated	2125
nitric	1271
ditto, highly concentrated	1580
muriatic	1194
red, acetous	1025
white, acetous	1014
distilled ditto	1010
fluoric	1500
acetic	1063
phosphoric	1558
formic	994
Alcohol, commercial	837
highly rectified	829
mixed with water,	
15-16ths alcohol	853
14-16ths "	867
13-16ths "	882
12-16ths "	895
11-16ths "	908
10-16ths "	920
9-16ths "	932
8-16ths "	943
7-16ths "	952
6-16ths "	960
5-16ths "	967
4-16ths "	973
3-16ths "	979
2-16ths "	985
1-16th "	992
Ammoniac, liquid	897
Beer, pale	1023
brown	1034
Cider	1018
Ether, sulphuric	739
nitric	909
muriatic	730
acetic	866
Milk, woman's	1020
cow's	1032
ass's	1036
ewe's	1041
goat's	1035
mare's	1034
cow's clarified	1019
Oil, essential, of turpentine	870
ditto, of lavender	894
ditto, of cloves	1036
ditto, of cinnamon	1044
of olives	915
of sweet almonds	917
of filberts	916
linseed	940
of walnuts	923
of whale	923
of hempseed	926
of poppies	924
rapeseed	919
Turpentine, liquid	991
Urine, human	1011
Water, rain	1000
distilled	1000
sea (average)	1026
of Dead Sea	1240
Wine, Burgundy	992

	Ounces
Wine, Bourdeaux	994
Madeira	1038
Port	997
Canary	1033

Resins, Gums, Animal Substances, &c.

Aloes, socotrine	1380
hepatic	1359
Asafœtida	1328
Bees-wax, yellow	965
white	969
Bone of an ox	1656
Butter	942
Calculus humanus	1700
ditto	1240
ditto	1434
Camphor	989
Copal, opaque	1149
Madagascar	1060
Chinese	1063
Crassamentum, human blood	1126
Dragon's blood	1205
Elemi	1018
Fat, beef	923
Galbanum	1212
Gamboge	1222
Gum, ammoniac	1207
Arabic	1452
Euphorbia	1124
seraphic	1201
tragacanth	1316
bdellium	1372
Scammony of Smyrna	1274
Gunpowder, shaken	932
in a loose heap	836
solid	1745
Honey	1450
Indigo	769
Ivory	1826
Juice of liquorice	1723
of Acacia	1515
Labdanum	1186
Lard	948
Mastic	1074
Myrrh	1360
Opium	1336
Serum of human blood	1030
Spermaceti	943
Storax	1110
Tallow	942
Terra Japonica	1398
Wax, shoemakers'	897

Woods.

Alder	800
Apple-tree	793
Ash, the trunk	845
Bay-tree	822
Beech	852
Box, French	912
Dutch	1328
Brazilian red	1031
Cedar, wild	596
Palestine	613
Indian	1315
American	561
Citron	726
Cocoa-wood	1040
Cherry-tree	715
Cork	240
Cypress, Spanish	644

	Ounces.		Ounces.
Ebony, American	1331	Medlar	944
Indian	1209	Mulberry, Spanish	897
Elder-tree	695	Oak, heart of, 60 years old	1170
Elm, trunk of	671	Olive-tree	927
Filbert-tree	600	Orange-tree	70[illegible]
Fir, male	550	Pear-tree	661
female	498	Pomegranate-tree	1354
Hazel	600	Poplar	383
Jasmine, Spanish	770	white Spanish	529
Juniper-tree	556	Plum-tree	785
Lemon-tree	703	Quince-tree	705
Lignum-vitæ	1333	Sassafras	482
Linden-tree	604	Vine	1327
Logwood	913	Walnut	671
Mastick-tree	849	Willow	585
Mahogany	1063	Yew, Dutch	788
Maple	750	Spanish	807

Weight and Specific Gravity of different Gases.

Fahrenheit's Thermometer 55°. Barometer 30 inches.

	Specific Gravity.	Wt. Cub. Foot.
Atmospheric air	1·2	525·0 grains.
Hydrogen gas	0·1	43·75
Oxygen gas	1·435	627·812
Azotic gas	1·182	517·125
Nitrous gas	1·4544	636·333
Ammoniac gas	·7311	319·832
Sulphureous acid gas	2·7611	1207·978

In this table the weights and specific gravities of the principal gases are given, as they correspond to a state of the barometer and thermometer which may be chosen for a medium. The specific gravity of any one gas to that of another will not exactly conform to the same ratio under different degrees of heat and other pressures of the atmosphere.

And if common air, the standard, be taken at unity (1), chlorine oxymuriatic acid will be 2·500, and hydrogen 0·069; whence we conclude that chlorine is $2\frac{1}{2}$ times heavier than hydrogen, and this last is 14 times lighter than common air. For, to arrive at the absolute weight of the gases, we have only to assume 100 cubic inches of atmospheric air to weigh 30·5 grains, and as there are 1728 cubical inches in a cubic foot, the simple proportion

$$100 : 30·5 \text{ grains} :: 1728 : 527·04 \text{ grains},$$

the weight of a cubic foot of common air.

And for any other gas, it is only necessary to observe its specific gravity in relation to that of common air; for example, chlorine has a specific gravity of 2·5; hence a cubic foot of chlorine will weigh $2\frac{1}{2}$ times as much as a cubic foot of common air; for

$$527·04 \times 2\tfrac{1}{2} = 1317·6 \text{ grains},$$

the weight of a cubic foot of chlorine.

To determine the weight of any gas lighter than common air, we also compare their specific gravities: thus, the specific gravity of ammoniacal gas is 0·5, and that of atmospheric air being $= 1$, we have $1 : 0·5 :: 1728 : 864·0$, or simply $1728 \div 2 = 864$ grains, for the weight of a cubic foot of ammoniacal gas; and so on for all the other gaseous bodies, as they are arranged in the following table.

If atmospheric air be taken at unity (1), then the various gases will stand as under:—

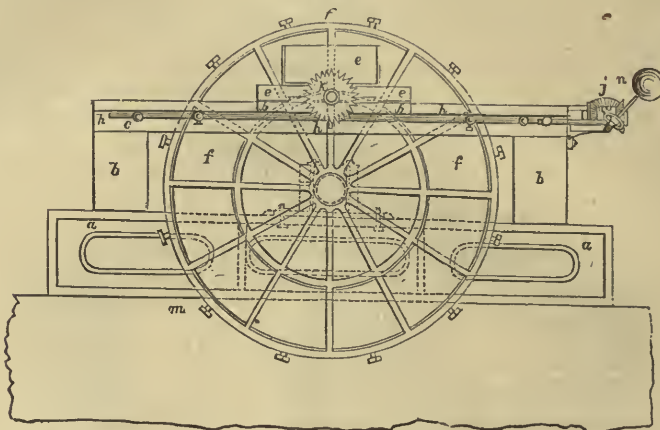
Atmospheric air	1·000	Hydrogen	0·69
Ammoniacal gas	0·500	Muriatic acid	1·284
Carbonic acid	1·527	Nitric oxide	1·041
Carbonic oxide	0·972	Nitrogen	0·972
Carburetted hydrogen	0·972	Nitrous acid	2·638
Chlorine	2·500	Nitrous oxide	1·527
Chlorocarboneous acid	3·472	Oxygen	1·111
Chloroprussic acid	2·152	Phosphuretted hydrogen	0·902
Cyanogen	1·805	Prussic acid	0·937
Euchlorine	2·440	Subcarburetted hydrogen	0·555
Fluoboric acid	2·371	Subphosphuretted ditto	0·972
Fluosilicic acid	3·632	Sulphuretted ditto	1·180
Hydriodic acid	4·346	Sulphureous acid	2·222

GRINDING MACHINE, *double*. By Messrs. Nasmyth, Gaskell and Co. The object of the machine represented by Figs. 2201, 2202, and 2203, is to grind up the faces of the different parts of machinery, when a great surface is required to be made perfectly smooth; to accomplish which, this contrivance has been used.

Figs. 2201, 2202, and 2203, severally show a side elevation, an end elevation, and a plan of a double-face grinding machine, the one side being a repetition of the other. To the two cast-iron cross-frames *a a*

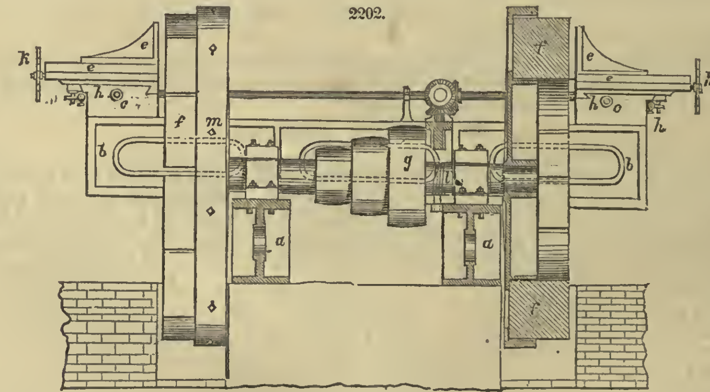
are bolted two large plummer-blocks for carrying the main shaft, having at each extremity the circular frames divided into twelve compartments, in which are placed the grinding stones *f*, each being adjustable by the small set screws *m* round its circumference. On the top of the cross-frames *a*, are placed two longitudinal frames *b b*, made also of cast-iron, for supporting the long bed-frames *c c*, and also the self-acting apparatus furnished to this machine. Two motions, the one at right angles to the other, are given by the slides *d* working along the beds *c*, and also the face-plates *e* for carrying the work, by which it is brought into contact with the grinding stones. Pits are made to allow the wheels, for carrying the stones, to work in.

2201.



The self-acting motion given to the work being faced, by means of which it slides along the bed *c* while the grinding stones are revolving on their axes, is thus obtained: on the main shaft next to the driving-riggers or pulleys *g*, is a worm *l*, which, as it revolves, works a worm-wheel represented by the dotted lines in Fig. 2202, thus communicating the motion to the upright spindle; from this it is carried by the bevel-wheels to the spindle running horizontally the whole length of the machine, having at each extremity three small bevel-wheels. The action of this apparatus is thus, supposing the slide to be travelling in the direction towards the small bevel-wheels, two of which are required for the purpose, while the third or outer one runs freely on the spindle, without producing any effect, the small

2202.

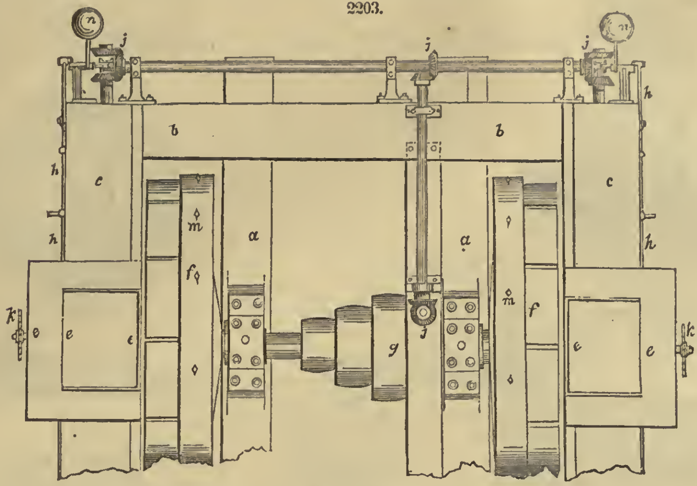


clutch being disengaged from it; on the travelling slide *d* is fixed a stud or pin *h'*; a long rod *h* of the same length as the bed *c*, is movable in two stud-bearings fixed to it. As the slide *d* travels, the pin *h'* comes into contact with a second stud or pin adjusted to any position on the rod *h*, according to the length of the motion required, which must naturally press it forward, and thereby throw out the clutch on the end of the spindle, which being shifted from one bevel-wheel to the other, disengages that which had been at work before, while it engages the outer one, that had been running loosely on the spindle; by this curious contrivance, the screw for working the slide revolves in a contrary direction, and instead of drawing the slide *d* towards it, sends it back. A counterbalance weight *n* is connected to the extremity of the rod *h*, for keeping it in a steady position while this operation is being performed.

The tappet-wheel *k*, fixed on the end of the screw for advancing the other slide *e*, is also worked by a pin on the same rod *h*, whereby the work is advanced to the face of the grinding stone; it is on the upper part of the slide *e* that the work is fixed. A substantial foundation, consisting of stone-work, is prepared for receiving the two frames *a a*, and to which they are firmly bolted down by strong holding-bolts.

Another mode of performing this same operation might be adopted, by fastening a whole grindstone into the chucks, and passing a bolt through two surface plates of two feet diameter each, one on the middle part of each face of the grindstone, by which means they would be more effectually secured in their places.

2203.



References to Figs. 2201, 2202, and 2203.

a, cross-frames or standards.
b, Longitudinal frames.
c, Bed-plates.
d, Cross-slides.
e, Slides or face-plates for carrying work.
f, Grindstones.
g, Driving-riggers.
h, Rods for reversing motion by means of tappet *h'* and clutches *i*.
i, Clutches.
j, Bevel-wheels for working slides.
k, Tappet-wheels.
l, Worm on main shaft for working bevel-gear *j*.
m, Screws for setting stones.
n, Counterbalance weights.

GRINDING MILL, *Bogardus' Eccentric.* This is the first modern improvement in mills—the old and hitherto unchanged principle is abandoned, and an entirely new one practically applied. In all others one stone or plate is stationary, and the other revolves, by its rapid revolution communicating a centrifugal force to the substance introduced between the plates, and thus placing it where it may be subjected to their grinding action. In this mill both plates revolve in the same direction, (with nearly equal speed,) on centres which are apart from each other one inch more or less, the centre of the one, or axis thereto affixed, resting on and revolving upon a stationary bearing, whilst the prime mover, by means of a belt or gearing, causes the motion of the other plate.

Fig. 2204 represents the plates used in this mill; *a* is the upper, *c* the lower plate, the faces of which are shown in the horizontal view. The vertical view in which the plates are marked *c d*, represents the position they occupy in reference to each other. From the position of the two centres it is named *the Eccentric Mill.* The circles which are cut in the plates act like revolving shears, cutting every way with a peculiar cutting, wrenching, twisting and sliding motion, admirably adapted for every species of grinding.

Fig. 2205 shows the mill for grinding *dry substances;* the power is applied by means of a belt and pulley attached to the shaft, and the lower plate *c c* is made to revolve, and communicates motion to the upper plate, which is fastened by bolts *d d* to the revolving collar *f f.* The shoe *l*, acts against the collar or tube, which causes it to vibrate, and this vibration hastens the supply fed to the plates to the extent allowed by the slide in the hopper. *i i* and *j* are oil-chambers; *h* the bearing for mill-shaft. The degree of fineness or coarseness of grinding is regulated by means of a screw and lever acting upon the step *g*. *e* is the screw, which may be turned by a wrench; *a* the lever, with a fulcrum *k*, and connected by means of a connecting-rod, represented by the dotted line in the stand, with a lever which acts directly upon the step. The weight *b*, by means of these levers would keep the plates in close contact, but their distance apart is regulated by the screw. As will be immediately perceived, when iron or any kindred substance passes between the plates, the lower plate yields and allows it to pass out.

Fig. 2206 represents the mill for grinding liquid substances. The principle is precisely the same; the only difference between this and the mill for grinding dry substances being in the arrangement of the frame, and the adaptation of the different parts to the particular use for which the mill is designed. The hopper acts as a mixer, and the liquid is forced down through the hollow shaft to the plates. The lower plate is plain for about two inches from the outer edge.

The following are some of the advantages of mills worked on this principle:

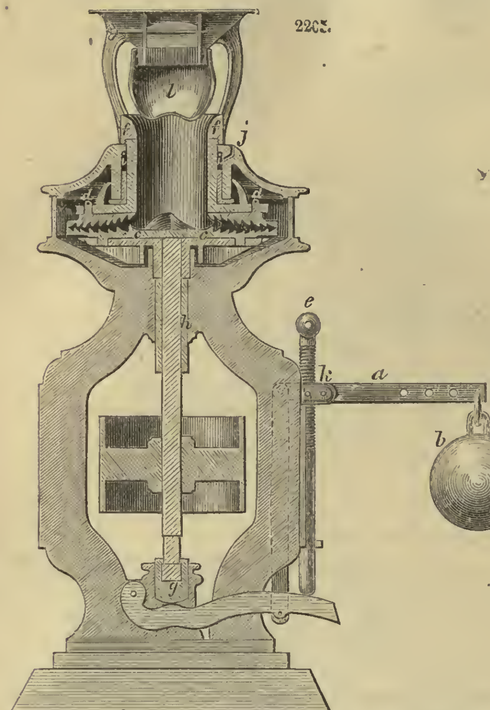
1. The peculiar motion of the plates causes them of themselves to discharge the ground substance, so that many substances can be ground in this which would altogether choke other mills.

2. In other mills a given point in one of the plates continually describes the same circle on the other, but in this mill it traverses on the other plate in an infinite variety of directions over a surface embraced between two concentric circles, apart from each other twice the distance that the centres of the plates are

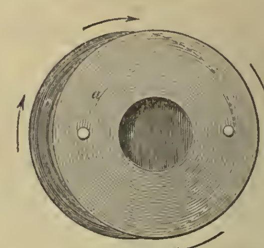
apart; thus the wear and tear of the plates is rendered uniform, and the grinding action of every part preserved.

3. In other mills the grinding power of each point increases with its distance from the centre, but in this mill, every point from the centre to the circumference has the same grinding power. A considerably smaller mill will therefore do a given amount of work, and accordingly the eccentric mill is more portable than any other

2205.

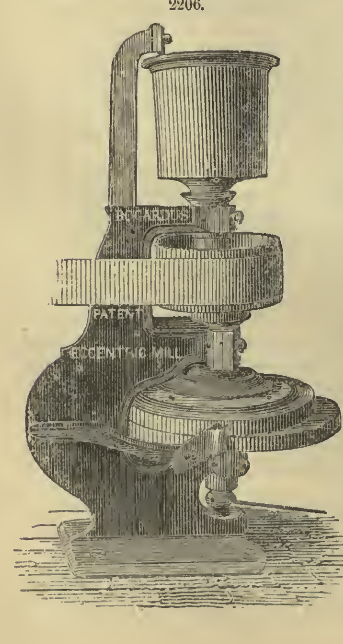


2204.



4. The ever-changing action of the mill, and the quick discharge of the substance ground, prevent the plates from becoming heated, so that it may be profitably employed in grinding substances which in other mills would be either spoiled or deteriorated in quality, or which could not be ground at all, on account of their melting. It is very extensively used for grinding sugar, a substance which it is almost impossible to grind in the old mills. If other mills were driven with the speed which can be safely applied to the eccentric mill, they would in a few minutes be heated to a very high degree.

2206.



These mills have been successfully introduced for the following purposes:—Hulling rice, coffee and olives; grinding grain of all kinds; paints of all kinds, in water or in oil; iron, zinc, copper and gold ores, plumbago and manganese, bones for manure and bones for refining sugar, flint and quartz, charcoal, plaster, putty, printers' inks, drugs and dye-stuffs, snuff, mustard, coffee, spices, loaf-sugar, starch, gums, resins, asphaltum, India-rubber, flaxseed and oil-cake, &c.

Many substances above enumerated cannot be ground at all by other mills. These mills are more economical in the power required to drive them, and the labor of attending to them is less costly for the work they do; they are more portable, and are capable of being applied to purposes for which other mills are useless. The wear and tear is trifling.

GRIND-STONES. A well-known tool, used in nearly all branches of the mechanic arts. They are brought to this country from France and England, and are also obtained in this country. The sandstone from which they are almost entirely composed is split out of the quarry by wedges, and dressed on the sides by chisel and hammer. A square hole, in proportion to the weight, is cut in the centre, and the stone marked from this centre; the face is then chipped down, as near as may be, to its intended circumference, and sent to market. After mounting and wedging the stone upon its axle, it is chipped off at the prominent points and then rough-turned—the heavy stones in particular requiring great care in the hanging and trimming, that they may run smoothly

GUDGEON. The extremity of a horizontal shaft of a water-wheel, that runs in the collar. Every gudgeon, in order to avoid unnecessary friction, should be made as small in diameter as possible, consistently with the requisite strength and durability. The cube root of the weight of a water-wheel in hundred weights, is nearly equal to the diameter in inches of a cast-iron gudgeon sufficiently strong to support such wheel. For wooden water-wheels, multiply the diameter in feet by the width also in feet, to which add the square of half the diameter; the cube root of the sum will be nearly equal to the diameter of the gudgeon in inches. It has been inferred from experiment that gudgeons of the same size, of cast and of wrought iron, are capable, at a medium, of sustaining weights without flexure, in the proportion of 9 to 14. See GEERING, page 841.

GUNS. Every best finished gun usually passes through fifteen or sixteen hands, each of which constitutes almost a distinct trade; although two or three branches are often combined, or subdivided, according to the extent of business. They may be arranged in the following order:—

1. Barrel forger; 2. lock and furniture forger; 3. barrel borer and filer; 4. lock filer; 5. furniture filer; 6. ribber and breecher; 7. stocker; 8. screwer-together; 9. detonator; 10. stripper and finisher; 11. lock finisher; 12. polisher and hardener; 13. engraver; 14. browner; 15. stock polisher. The barrel-making being also divided into several branches.

The first process in the manufacture of musket or common barrels is the making what are technically called *skelps.* The skelp is a piece of iron about one foot long, but thicker and broader at one end than at the other; and the barrel of a musket is formed by forging out such pieces to the proper dimensions, and then folding or bending them round into a cylindrical form until the edges overlap, so that they can be welded together. It is then placed in a furnace, raised to a welding heat, and taken out, when a triblet or cylinder of iron being placed in it, it is passed quickly through a pair of rollers. The effect of this is, that the welding is performed at a single heating, and the remainder of the elongation necessary for bringing it to the length of a musket-barrel is performed in a similar manner, but at a lower temperature. This method of welding is far less injurious to the texture of the iron, which is now exposed only once, instead of three or four times to the welding heat.

The barrels for fowling-pieces are of various kinds, as *stub, stub-twist, wire-twist,* and *Damascus-twist,* and sometimes a combination of the two latter ones, as well as another description called *stub-Damascus.* These are the best varieties, but a number of inferior kinds are made, which are only employed for very common guns.

In order to make *stub*-iron, old horse-shoe nails, called *stubs,* are collected, then packed closely together, and bound with an iron hoop, so as to form a ball about ten or twelve inches in circumference; which, being put into a furnace or forge-fire, and raised to a welding heat, is united by hammering, and drawn out into bars of convenient lengths, for the purposes intended. This method is adopted for the locks, furniture, and breechings of all best guns, and is to a certain extent practised for barrels, though not so much as formerly, more expeditious methods being employed on a large scale.

The most approved modern method of converting them into gun-barrels, (after carefully sorting and picking them, to see that no cast-iron or impurities are mixed with them,) is first to put about half a hundred weight into a large cast-iron drum or cylinder, crossed internally with iron bars, through the centre of which a shaft passes, which is connected by a strap with the steam-engine, and the revolution of the drum actually polishes the nails by their friction against each other; they are then sifted, by which every particle of dust is removed. The steel intended to be mixed with them is clipped by means of large shears, worked by the engine into small pieces, corresponding in size to the stubs, and afterwards cleansed by a similar process. About 40 lbs. are thrown on to the inclined hearth of an air-furnace, where they are *puddled* or mixed together with a long iron rod, and withdrawn in a mass called a *bloom,* almost in a state of fusion, to be welded under a hammer of three tons weight, by which it is formed into a long square block: this being put in, at another door of the same air-furnace, is raised to a bright red-heat, and drawn out under a tilt-hammer of a ton and a half weight, into bars of a proper size to pass the rollers, by means of which it is reduced to rods of the required size. The air-furnace having two doors prevents any loss of time, as the moment one ball of stubs is withdrawn, another charge is put in, and the two operations go on together, keeping both hammers employed. The iron thus produced is very tough, and free from specks or grays, but stubs are hardly ever used alone, as they were formerly, being too soft; therefore, a portion of steel is mixed with them, which varies from one-eighth to one-half of the whole mass. It need hardly be remarked, that the advantage to be derived from the use of horse-shoe nails does not arise from any virtue in the horse's hoof, as some have imagined, but simply because good iron is, or ought to be, originally employed for the purpose, otherwise the nails will not drive into the hoof; and the iron, being worked much more, is freed from its impurities, which can only be effected by repeated workings.

When gun-barrels are manufactured from stub-iron by a process similar to that of musket-barrels, they merely exhibit a mottled appearance on the application of acids. It is also usual to make what are called *stub* barrels from *scrap* iron cut into small pieces by means of shears worked by the engine. It would be difficult to define what scrap iron is, or what it is not, being composed of every thing in iron that has previously been manufactured, as well as of the cuttings from the various manufactories; these are sorted and employed in preparing iron of various qualities, known by the names of *wire*-twist, *Damascus*-twist, *stub*-twist, *charcoal* iron, *threepenny skelp* iron, *twopenny skelp,* &c.

The object of preparing iron from small pieces, is to cross and interweave the fibres in every possible direction, and thus greatly to increase its tenacity. Very few *plain stub* barrels are now made, as iron of inferior quality, when *twisted,* finds a more ready sale. For the finest description of barrels, a certain proportion of scrap steel, such as broken coach-springs, is cut into pieces and mixed with the iron by the operation called *puddling,* by which the steel loses a considerable portion of its carbon, and becomes converted into *mild* steel, uniting readily with the iron, and greatly increasing the variegation and beauty of the twist. In whatever manner the *iron* may be prepared, the operation of drawing it out into ribands for twisting is the same. This is effected by passing the bars, while red-hot, between

rollers until extended several yards in length, about half an inch wide, and varying in thickness according to whichever part of the barrel it may be intended to form: these ribands are cut into convenient lengths, each being sufficient to form one-third of a barrel: one of these pieces is made red-hot and twisted into a spiral form, by placing one end in the prong of an iron rod, which passes through a frame, and is turned by a handle, the riband being prevented from going round without twisting by means of an iron bar placed parallel to the revolving rod. The spiral thus formed is raised to a welding heat, and dropped on to a cylindrical iron rod, which being struck forcibly on the ground, (*jumped*,) the edges of the spiral unite, and the welding is then completed by hammering on the anvil: the other spirals are added according to the length of the barrel, and the forging is finished by hammering regularly all over. The ends of each spiral should be turned up and united at each junction of the spirals, to avoid the confusion in the twist occasioned by merely dropping one spiral on another; but this is rarely done. Wire-twist, of any degree of fineness, may be obtained by welding alternate laminæ of iron and steel, or iron of two qualities, together; the compound bar thus formed is drawn into ribands, and twisted in the same manner as the preceding. The operation of twisting the iron not only increases the beauty of the barrel, but adds considerably to its strength by opposing the longitudinal direction of the fibres to the expansion that takes place in the act of firing. The iron called *Damascus*, from its resemblance to the celebrated Oriental barrels and sword-blades, is now manufactured by welding 25 bars of iron and *mild steel* alternately, each about 2 feet long, 2 inches wide, and ¼ of an inch thick; and having drawn the whole mass into a long bar, or rod, ⅜ of an inch square, it is then cut into proper lengths of from five to six feet; one of these pieces being made red-hot, is held firmly in a vice, or in a square hole, to prevent it from turning, while the other end is twisted by a *brace*, or by machinery, taking care that the turns are regular, and holding those parts which turn closer than others with a pair of tongs; the rod is by this means shortened to half its original length, and made quite round. If only two pieces are employed to form the riband, one is turned to the right, and the other to the left; these being laid parallel to each other, are united by welding, and then flattened; but if three square rods are used, the centre one is turned in a contrary direction to the outside ones, and this produces the handsomest figure. By these operations the alternations of iron and steel change places at every half revolution of the square rod composed of twenty-five laminæ; the external layers winding round the interior ones, thus forming, when flattened into a riband, irregular concentric ovals or circles. The fineness of the Damascus depends on the number and thickness of the alternations; and the figure of the riband when brought out by acids resembles that of a curled ostrich feather; but when wound into a spiral form, and united on its edges by *jumping*, the edges bend round and the figure is completed. This is sometimes veneered on common iron; and they often wind a thin riband of Damascus, or superior iron, round iron of the worst quality; even gas tubing is considered good enough, when coated in this manner, to form gun-barrels of a very low price with a high-priced appearance. Stub Damascus is merely one square rod of Damascus iron twisted and flattened into the riband for forming the barrel.

Damascus and wire-twist is a riband of each, twisted together to make a greater variety; but there is no quality so good as the best regular *stub-twist*. The Swedish iron, known by the mark C C N D, and coach-springs, form an excellent combination for Damascus barrels. The next operation to forging is rough boring; this is usually performed by machinery. A long square *bit*, attached to a rod, revolves with great rapidity, while the barrel is pressed forward by a crooked lever, one end of which the workman holds, and passes the other end along a series of nails or pegs, driven into the top edge of the trough or bench, on which the barrel is placed, thus forcing the barrel forward along the boring-bit. Water is kept constantly flowing over the barrel during the process, otherwise the heat generated by the friction would soon soften the bit, and render it useless. The outsides are then ground on very broad stones turned by the engine; the workman sits on a kind of wooden horse, firmly chained to the floor; a sloping board, nearly in contact with the grindstone, is placed before him, against which he leans, and rests the barrel; a long iron rod passes through the barrel, and projects at each end, sufficiently to form handles, and at the same time an axis, on which the barrel rotates more or less freely, according to the degree of pressure against the board. By moving it regularly sideways, the whole surface is ground over. It is evidently impossible to finish barrels with any great accuracy on a grindstone, though most of the barrels that are made into guns in Birmingham are merely smoothed up after this process—an appearance of regularity being given to them at the muzzle by filing; but if transverse sections were made at different distances, they would be found very unequal in substance, as is always the case with musket and other common barrels, although some of the grinders are able to finish with considerable accuracy. It is in the ground and rough-bored state that most of the best barrels are sent to the finishing gun-smith, where, after being set perfectly straight, they are fixed on a movable carriage, which is drawn gradually forward along a level surface or railway, by means of a weight and pulleys; the boring-bit being fixed in a square hole in the axis of a fly-wheel which is turned by hand or by steam machinery, while the barrel slowly advances until the bit passes out at the opposite end to that at which it entered. The same square bit is made to enlarge the bore to the required size by the addition of a *spill*, which is simply a long thin piece of wood slightly taper, flat on one side and round on the other: this being placed along one side of the bit, causes it to cut on two angles only, and the size of the caliber may be very gradually increased by the interposition of strips of writing-paper between the *spill* and the bit. After the barrel is correctly bored, the external part is turned in a lathe; a steel mandril being introduced at each end. The barrel is thus rendered perfectly correct and equal in every part. The barrel being *tapped*, that is, screwed at the breech end, and the plug fitted, is now proved with a charge of powder proportioned to the weight of a leaden ball that fits the bore; this is always five or six times the ordinary load; besides which, it is forced with water, as minute defects, invisible to the eye and not affected by the proving, are thus easily detected. When *false-breeched*, *ribbed*, *stocked*, and *screwed together*, the barrel is bored for shooting, and smoothed outside. Double barrels have a flat struck along the inner side of each, previous to laying them together

about four inches of the breech end is brazed, or hard soldered, and the remainder of the length *soft* soldered; the upper and under ribs being soldered on at the same time.

The progressive stages of best gun-making may be briefly enumerated in the following order, supposing the lock and barrel to be already made. The lock and barrel being jointed to each other, (if the plan require it,) are given to the stocker, who lets them into the wood, which ought to have been previously cut out of the plank at least two or three years, in order to be perfectly seasoned. The next workman is the screwer-together, who lets in all the furniture and puts in all the screws: when this is done, the gun is detonated by another workman who fits the cock, and finishes the external part of the breeching. The barrel then goes to the barrel-maker to smooth and bore for shooting, and the gun is returned to the screwer-together. From him it passes to the *stripper* and *finisher*, who takes the whole to pieces and corrects any trifling errors of preceding workmen. The barrel is engraved, browned; an operation performed by producing successive coatings of rust on the surface, and brushing them off as they arise with a fine steel wire *scratch-brush*, until the required color be obtained, which usually takes a week, and is effected by a solution of metallic salts, combined with nitric ether; during this process the lock and furniture are polished, engraved, blued, and hardened, and the stock is oiled and polished. The hardening is performed by stratifying the various parts in an iron pan, with animal charcoal, prepared from bone and ivory-dust, or old shoes: the whole is then exposed to a full red-heat for about an hour, or according to the size of the work, the pan is withdrawn from the fire, and the contents thrown into water. The surface of the iron becomes converted into steel by the absorption of the carbon, and beautiful colors are produced, the variegation of the color being affected by the quantity of the iron. The whole of the parts now return to the finisher, and the gun is completed.

Rifled barrels are only used for throwing balls; they are always much thicker and heavier than other barrels, in order to render the aim more steady, as well as to admit of cutting the grooves with safety. Rifling consists in cutting a number of grooves in a spiral direction down the inside of a barrel, usually from seven to fifteen, dividing the interior surface into *lands* and *furrows*, the sunk parts being called the *furrows*, and the original surface left, the *lands*. In order to diminish friction, as well as to impress the ball more readily, the lands ought to be narrower than the furrows. The object of rifling is to give to the ball a rotation coincident with the line of its flight, and thus to correct the variable rotation which every ball, passing freely along a smooth-bored barrel, receives from its friction against the sides. The latter rotation never can coincide with the axis of the barrel, but must have a tendency to deflect the ball from the line of aim, according to the last impulse it may receive on quitting the barrel. Rifling also corrects any inequality in the density of the ball itself, by causing it to present alternately every part of its surface in its passage through the air.

The usual method of rifling a barrel is by means of a long square bar, or rod of steel, which is twisted to the required degree of curvature, and then accurately ground with oil and emery in square holes, so as to render every portion of its length precisely equal in curvature, which operation requires considerable care and time. There are generally several rods of this kind to each rifling-bench, of different curves, so as to vary from three-fourths of a turn, to a turn and a half, in three feet; but should any other curve be required for experimental purposes, a new rod must be made for each, which becomes expensive.

A rod of this description is correctly fitted into square holes, in two *puppets*, or heads, similar to those of a lathe, through which it can be freely drawn backward and forward by means of a cross handle, turning on its centre, to which is attached a dividing-plate to regulate the cuts or grooves. The barrel being bored perfectly true, is fixed to the end of a long bench opposite to, and in a direct line with, the rifling-rod at the other end. A piece of wood is turned to fit the barrel, in which a longitudinal groove is sunk to receive the cutter, which is made of tempered steel, and has ten or twelve sloping teeth in it. The piece of wood screws on to the rifling-rod by means of an iron ferrule; and at the commencement the teeth of the cutter only project very slightly beyond the surface of the wood. The cylinder of wood being entered into the barrel, the rifling-rod is pushed forward, and the projecting teeth of the cutter make a faint groove in a spiral direction down the inside of the barrel: the rod is worked backward and forward, until the teeth cease to cut, when the wood is withdrawn, and the rod turned an equal division of a circle by means of the dividing-plate, according to the number of grooves intended to be made: it is again entered, and another faint groove cut, and so on, until all the grooves are sunk to the same depth as the first. The wood is again withdrawn, and the cutter elevated a little, by taking it out of the groove in the wood, and placing underneath one or two slips of writing-paper soaked in oil; the cutter being replaced, the same operation is repeated as at first, and the grooves are gradually cut to the desired depth by the successive addition of thin slips of paper. When the rifling is completed, an iron rod is placed in the centre of the barrel, and melted lead poured in, so as to occupy about eight inches of the barrel; which lead, of course, takes a perfect cast of the interior, and is afterwards charged with oil and fine emery, and drawn up and down the barrel to polish the inside, and remove the sharp edges left by the cutter. This operation is called *draw-boring.*

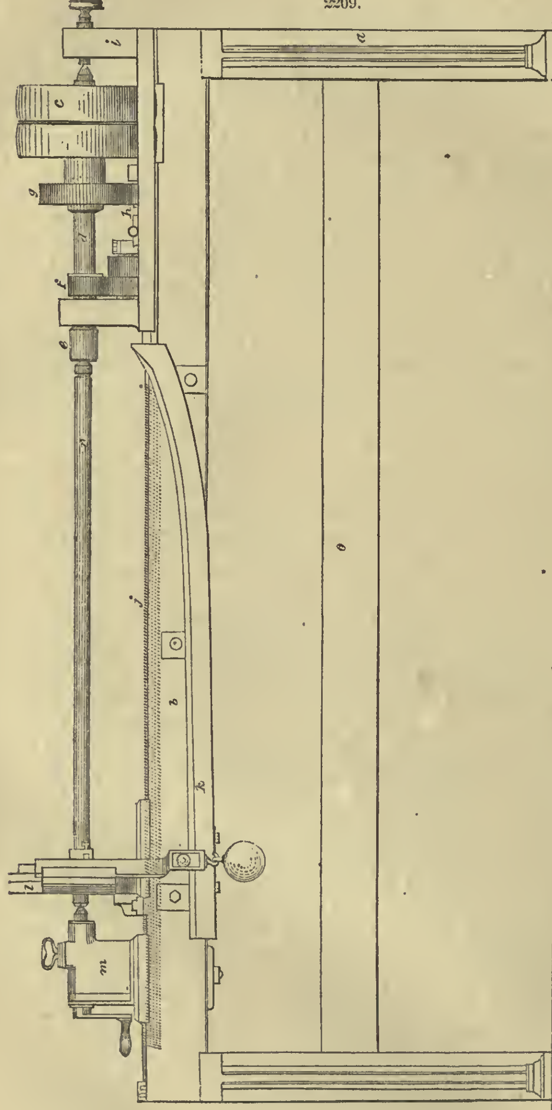
A barrel can be as accurately rifled by this means as by any other, if the rods be correctly made; but an improvement in rifling machines has been made, by which the twisted rod is altogether dispensed with, and any required curvature given by a round rod. The principal advantage of this machine is the facility it affords of varying the curvature of the spirals at pleasure, from a straight line to two turns in three feet. A long square horizontal bar, which moves at each end in segments of a circle, is attached to the centre of the bench: this bar can be fixed at any angle of inclination: above this is a carriage freely traversing a railroad, and in the middle of this carriage is the dividing-plate and rifling-rod, the latter being made to turn by means of a pinion-wheel and rack-work, which slides on the horizontal bar as the carriage is pushed backward and forward; all the other arrangements of wood and cutter being the same as with the twisted rod. This machine is now generally employed for best rifles, and the old plan for military rifles.

Machinery for the stocking of muskets has been adopted to a considerable extent in Europe and in

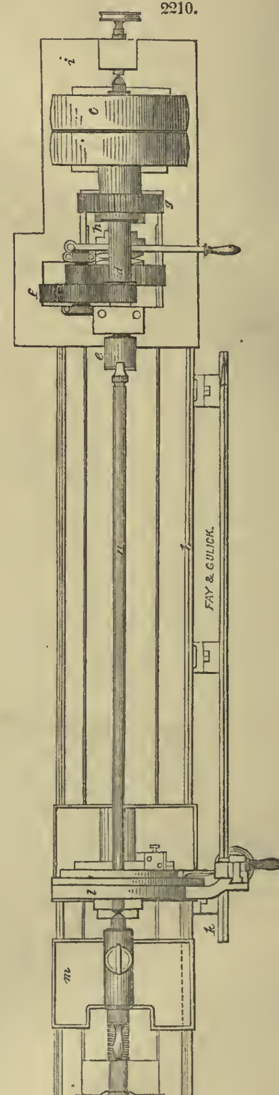
this country; the barrel, lock, and furniture being entirely let into the wood by this means. The machinery for turning gun-stocks, used only, we believe, in the manufactory of muskets, differs but little from the lathe for turning irregular bodies; of which machine two examples are given under the article LATHE, which see. The following machine for turning gun-barrels is in general use in the foreign government workshops.

GUN-BARRELS, *Lathe for Turning.* The object of this machine is to perform an operation entirely different from that produced by the several motions of the common turning-lathe. In this case, the curve required to be turned, on the whole length of the musket-barrel, is of an irregular form. This, as will be seen by Figs. 2209, 2210, 2211, and 2212, is effected by a very simple contrivance, as follows:

2209.



2210.

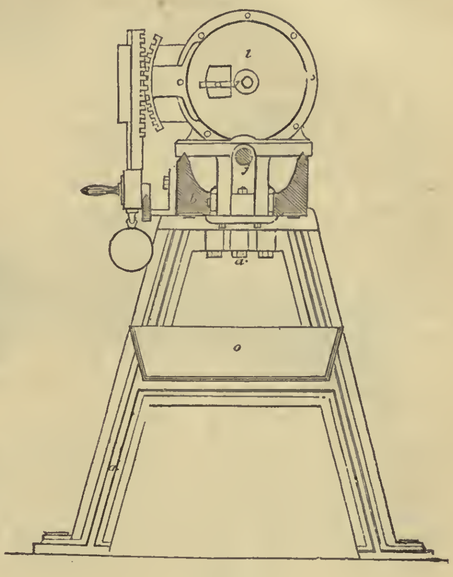


The bed b is secured by three bolts a' a' a' to the side frames or standards a a, which have also fixed to them a tank o for receiving the waste oil and the iron turnings from the barrel being turned; on the top of the bed is placed the headstock frame i, for carrying the several parts of the machinery; and on the mandril d are the tight and loose pulleys for giving motion to the machine: the centre c' of this mandril is adjusted by the back centre c''. By the two sets of spur-wheels and pinions a double motion is produced, the forward by f and the backward by g, which are alternately worked by means of the small clutch h, thus giving a revolving motion to the square-threaded screw j for advancing the tool

frame l along the barrel to be turned; this motion is made self-acting by means of two small bars $p\,p$ fixed to the clutch-lever, having projecting pieces on their sides, with which the frame l comes in contact, and pressing against them, draws them and engages the clutch in the wheels for giving the opposite motion, while the object of the handle h' is to disengage it by hand. The spindle on which these small wheels are fixed runs freely in brass bearings fitted to the headstock i.

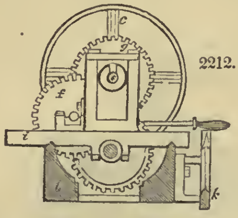
On the opposite end of the machine is the headstock m, having an adjustable centre c', worked by the screw and handle m'', and may be fixed in any required position by a small set-screw m'''; this head can be moved along the bed b, to suit the length of any barrel n, and by the cross-bar and bolts m' may be secured to it. The musket-barrel to be turned is slid on the long bar or mandril n', which it fits very tightly. One end of this mandril is then dropped in the chuck e for carrying it round, while it is centred at both ends in the centre pieces $c'\,c'$.

2211.



References of Figs. 2209, 2210, 2211, and 2212.

- a, Standards for supporting the bed.
- b, Bed of machine.
- c, Tight and loose pulleys.
- d, Mandril with centre pieces $c'\,c'$ and back centre c''.
- e, Chuck.
- f, Spur-wheels and pinions for producing the forward motion.
- g, Spur-wheels and pinions for producing the backward motion.
- h, Double clutch for changing the motions worked by the lever h'.
- i, Headstocks.
- j, Square-threaded screw for working alternately the frame l for carrying the tool.
- k, Curved bar screwed to the side of bed.
- l Frame or chuck for carrying the tools l' and securing the barrel in its proper position by means of the rack segment l'' and the vertical rack and weight l'''.
- m, Movable headstocks fixed to the bed by cross-bar and bolts m', the centre c working through it by the screw and handle m'', which may be fixed by a set-screw m'''.
- n, Barrel being turned fixed on a long mandril or bar n.
- o, Tank for receiving the turnings and waste oil, fixed to the standards.
- p, Sliding-bars fixed to the clutch at one end, by which means the machine is made self-acting.



2212.

The most curious part of this machine is the frame l for holding the tools, and likewise the barrel of the musket being turned; which latter operation is rendered rather difficult from the irregular shape of the barrel. Fig. 2211 shows a section, looking at the frame l, which consists of a back plate, on the face of which is a brass plate with the eccentric grooves shown by the dotted lines struck from different centres; between the latter plate and the back plate are four dies sliding in V's, having ribs working in the above grooves, which, not being concentric, press them against the barrel, and thereby hold it firmly while the tools l' are turning it; but as the diameter of the barrel alters, it is necessary to loosen the dies, in order to allow the frame l, of which they form part, to slide along the bed on its V's. This is thus effected: a curve bar or template k, suitable to the curve required by the barrel, is firmly screwed to the side of the bed, its upper edge k, Figs. 2211 and 2212, being of the shape of a V, on which the lower part of the rack l''' slides, the upper part working at the same time in the V's screwed to the projection given to the back plate l by three screws. Thus the motion produced by the curve of the bar k is transmitted through the rack and the segment l'' to the grooved plate on which the latter is fixed; the result of this is the tightening or loosening the four dies, which must naturally be the case, as they have ribs working in the grooves, which they are compelled to follow. By the weight suspended from the vertical rack, any irregular motion that might take place is entirely obviated, it being kept firmly working on the upper surface of the curved bar k, while the small handle is provided for the purpose of raising it by hand when required. There are two tools l', Fig. 2211, fixed to one of the four dies already described; the one farthest from the frame l is for rough turning, while the other follows it, giving the finishing cut.

A small bearing is provided on the bed for supporting the outer end of the screw j, and the standards are well secured to the floor by bolts for that purpose.

This machine is capable of turning and finishing three barrels per hour; and similar machines are in use at the Armory of Enfield, and twelve of them, in conjunction with a complete set of machinery for making muskets, are at work in the Imperial Armory at Constantinople, besides machines for the French government, and for the Pasha of Egypt.

Jennings' Patent American Rifle.—This weapon is, without doubt, the simplest, and at the same time one of the most perfect and effective of breech-loading arms. The gunpowder is contained *within* the ball, which is elongated for that purpose, something in the shape and appearance of a sewing thimble, closed at the end by a perforated cork. The range of the gun is very great, while from its simplicity it may be used for a long time without cleaning. The inventor is now engaged in simplifying the machinery of the lock still more, and arrangements have been perfected for manufacturing them on a large scale.

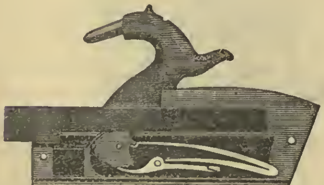
The appearance of the gun is so like the common percussion gun that an engraving is not necessary. The following description and reference to the mechanism of the lock will be sufficient. The agent for the sale of these weapons is C. P. Dixon, 177 Broadway, New York.

To raise the hammer or cock.—Put the right thumb on the hammer, and the right forefinger in the trigger-ring, and as the hammer is raised push the trigger-ring forward, or in other words, when the thumb and finger are so placed, the simple turning of the hand, the thumb back and the finger forward, brings down the *toggle* 4, Fig. 2213, which is behind the breech-pin, (this is necessary from the fact that a spring in the breech-pin 1 catches in the tumbler of the lock as the hammer is raised, breaking the breech-pin out from any stick there may be in the barrel,) and allows the breech-pin to be forced quite back; the cartridge can then be placed in the opening on the side of the lock, then, by pulling the trigger-ring 3 back, the cartridge is forced into the barrel, taking at the same time a priming (percussion pill) from the magazine on top, (which will hold from 50 to 70 pills,) and throws up the toggle in the rear of the breech-pin, when a harder pull fires the piece, which is effected by forcing the fire from the pill, through the touch-hole into the hole in the centre of the cork, in the cartridge. It is well to put in a cork or small wad to hold the first cartridge back against the breech-pin, though this is not absolutely necessary; after the first discharge this is not required, as the cork is left in the barrel, and is pushed out by each succeeding cartridge.

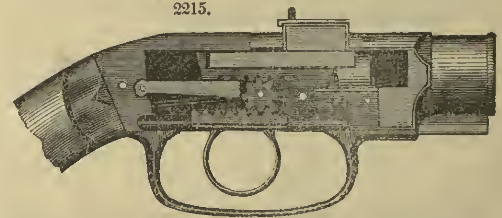
2213.

To clean the rifle.—Knock the pin out that secures the barrel to the breech, take off the barrel and the lock—the forward screw to the lock having a slight mark to distinguish it from the other—then take out the separate parts. When cleaned, put in first the button with the countersunk side down,

2214.



2215.



then the breech-pin, dropping it in so that the tail of the button will come between the two pins on the top of the breech-pin; then the *pinion* 2 with the dotted tooth in the last tooth of the breech-pin when it is clear forward, on which there is also a dot; then put in the trigger-rack, placing it as far back as it will go, then the toggle; then put on the lock, leaving the breech-pin clear forward, as only in this position will the end of the spring in the breech-pin fit into its place on the tumbler.

The Prussian breech-loading rifle.—The Prussian rifle, known by the name of the *Zund Nadel*, (darting needle,) has a number of points about it very different from all other breech-loading fire-arms, but we will state three of them before describing the engravings, to make the description easier to understand. First, it uses a different cartridge and no detonating powder, but a friction needle—*darting* needle, (*zund nadel*,) which pierces the bottom of the cartridge and ignites the powder by a friction combustible priming. All this is done inside, and it is certainly as efficacious in wet as in dry weather. Second, an air-chamber behind the cartridge, in which the expanded air acts to force out the ball Third, the sliding breech-pin, and the manner of operating and fastening it in an inclined butt of the breech.

Fig. 2216 is a view of the breech-pin separated from the barrel.

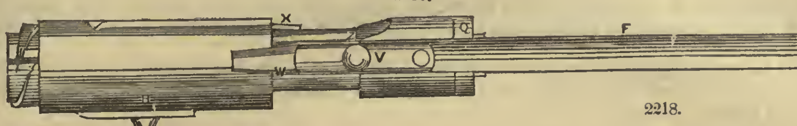
Fig. 2217 is a longitudinal vertical section, showing the interior.

Fig. 2218 is the cartridge. A is the picket bullet; B the friction combustible priming; C the paper-machie case.

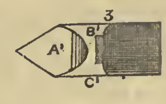
Fig. 2219 is a plan view of the rifle, and Fig. 2220 a side view. The same letters refer to like parts. here is a tube behind the breech of the barrel, forming a chamber, and there is a slot on its top for the

breech-pin to slide in. The breech-pin can be taken out entirely by unscrewing the cap Y. This is best seen in Fig. 2220: A is the barrel; it is enlarged at the breech to receive the breech-pin, the office of which is to open to put in the cartridge, and shut to enclose it perfectly, &c. B is the breech-pin with a short screw C, Fig. 2216, on its forward end, which, by a quarter turn, locks into the breech-butt of the barrel. G is a handle to operate the sliding breech-pin, which is of a tubular form. The breech-pin slides in the tube D. F is a projecting piece of the breech-pin, to guide the said pin when the cap Y is off and the pin put in the tube, also to guide it back and forth. The forward end H of the tube D is made of the form of the segment of a helix, so inclined that when the sliding breech-pin is pushed forward, after the cartridge is inserted in the breech-butt of the barrel, and then turned to the right to screw into the breech of the barrel, the forward shoulder of the projection F acting on the said inclined

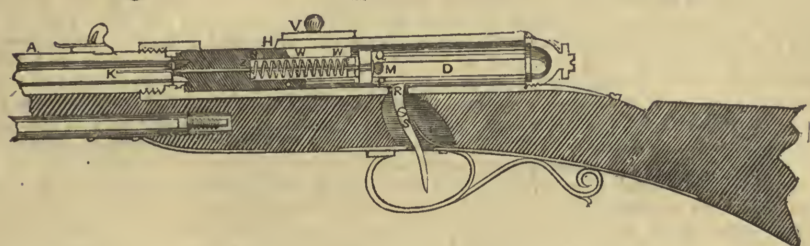
2216.




2218.

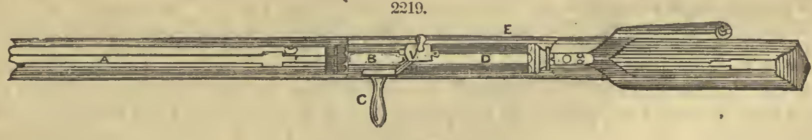


2217.

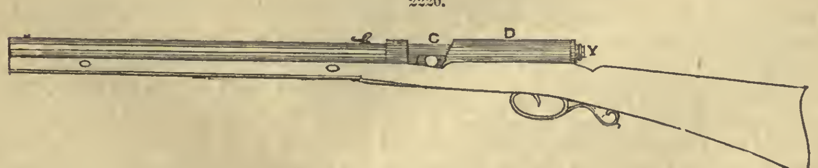


recess, will aid the thread in forcing in the breech-pin, and, during the discharge, will aid the screw-thread in resisting the recoil. In this way the breech-pin is held firmly in its place during the discharge of the piece—a very important combination indeed. The forward end of the breech-pin is a strong hollow air-chamber I, behind the cartridge, and the air contained therein is expanded by the combustion in the cartridge, and aids to force out the ball; this is in accordance with scientific experiments. In the centre of this hollow chamber is a projecting piece in which is drilled a centre hole, through which the darting steel-needle K projects and slides, Fig. 2217. This is the needle that pierces the cartridge and inflames the priming. The needle is secured to a small fly-spring carrier, something like that kind used in small guns for juveniles. L is this carrier; it has a coiled spring O abutting against its forward end, the dots, Fig. 2217, and abutting with its back end against a collar of the breech-pin, seen inside of the catch P of the carrier, which is attached by a screw to the head M of the needle. To load, the handle G is turned to the left, and the breech-pin drawn back in the top slot of the tube, when the carrier disk P is caught by the sear R of the trigger, the carrier held, and the cartridge is inserted in the butt of the

2219.



2220.



barrel. The breech-pin is then moved forward, and the shoulder turned into the inclined recess. By drawing the trigger S the carrier is disengaged, and the spring darts the needle K into the end of the cartridge to effect the discharge. U, Fig. 2216, is a ring of the tube, into which the breech-pin slides accurately, the said ring being placed forward of the disk P of the carrier. V is a bar which fits into the slot of the tube, and when the breech-pin is forced home and this bar pushed forward, it covers up the slot, and its forward end is fitted to enter a recess W in the breech-pin. When the breech-pin is locked in its place, and the bar V pushed in its place, there is thus a most effective bracing to prevent the breech-pin yielding in the least to the recoil of the discharger. X is a spring fitted into a recess of

the breech-pin, and it has a projecting catch (not seen) which passes into a hole in the breech-pin, to drop before the carrier when it is drawn back, to hold the carrier during the act of loading, to prevent accidents by the touch of the trigger; but when the gun is loaded, by pushing forward the bar V, the needle-carrier is relieved from this to be under the complete control of the trigger. Z is an incline on the bar that goes under the spring X, and draws out the stop in the interior when the bar V is pushed forward. All this is done at the breech.

The gun itself is compact and simple. The whole of the light cavalry of the Prussian army are to be provided with it. The inventor is Mr. Charles Hartung, of Prussia, now of New York. The assignee is John B. Klein, Esq., of Laight street, New York. It is patented in the United States.

Colt's improvements in fire-arms, patented in 1849, consist in certain improvements upon that construction of guns and pistols which has a cylindrical revolving breech-piece, provided with a series of parallel chambers for containing a series of charges, which charges, by the revolution of the breech upon its shaft, may be successively brought into a line with the bore of the barrel, and be severally discharged through the same.

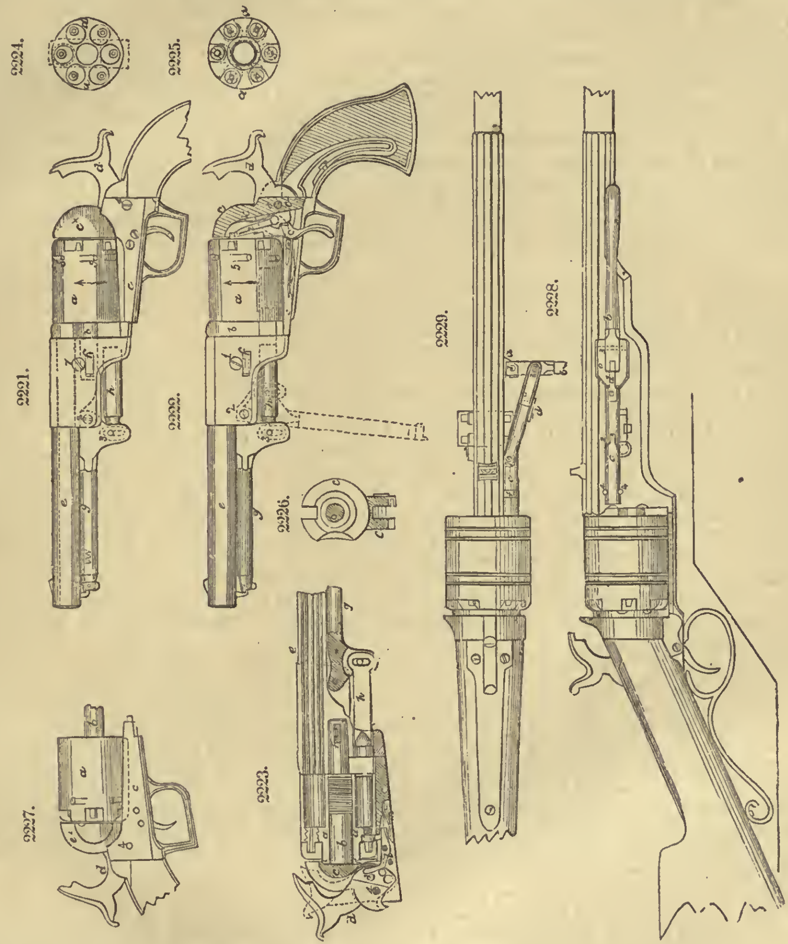
In the following figures the improvements constituting the present invention are shown as applied to this construction of fire-arms, which formed the subject of a patent granted to the present patentee on the 22d of October, 1835.

Fig. 2221 shows a pistol made according to this invention; Fig. 2222 is a side view, showing the lock-frame and recoil-shield in section; and Fig. 2223 is a longitudinal section, taken through the middle of the breech and barrel. *a* is the breech, containing six chambers, as shown in the end view, Fig. 2224, in the back of each of which a nipple is fitted, as shown in end view at Fig. 2225, and in section at Fig. 2223, to receive a percussion cap for firing the charge. This breech is supported by and is capable of turning on a spindle or arbor *b*, which is welded or fastened to and forms one piece with the recoil-shield *c**, it being in a line parallel to the axis of the barrel. The shield is itself a continuation of the lock-frame *c*, the whole being formed out of one solid piece of metal. By referring to the longitudinal section, Figs. 2222 and 2223, and to the cross section, Fig. 2226, the peculiar construction of this lock-frame and shield will be readily understood. The shield *c** stands up at right angles to the frame *c*, and forms a round head (somewhat like a bolt-head) to its shaft *b*. The upper part of the shield is recessed to receive the hammer *d*, when it is thrown forward to effect the discharge of the pistol; and a recess is also made in the piece of metal which constitutes the lock-frame and shield, (see Fig. 2222,) to receive the parts which respectively revolve the breech to bring round the charges in a line with the barrel *e*, and lock the breech to the frame for the purpose of insuring that the charges shall be in a line with the barrel before the firing takes place. When the pistol is on half-cock, or in the position shown at Fig. 2223, the breech is free to turn round on its arbor in the direction of the arrow, Figs. 2221 and 2222. It may then be loaded and primed with facility, without being removed from its place, as was formerly requisite in charging this construction of revolving-breech fire-arms; a free space being left in front of the mouths of the chambers, as will be seen by referring to the end view of this breech, Fig. 2224, which shows the sectional area of the barrel and its appendages in dotted lines. The barrel *e* is supported in its place by the end of the spindle *b*, fitting into a socket in a bracket-piece, forming one piece with the barrel, as shown best at Fig. 2223. Against the end of this socket the spindle is made to abut, and thus to determine the exact position of the barrel with respect to the face of the revolving breech. To keep the barrel secure in its place, a key *f* is introduced through slots in the bracket or projecting piece of the barrel, and through the spindle *b*, its upper edge acting on the forward end of the slot in the spindle, and its lower edge acting upon the lower end of the slots in the bracket of the barrel, the effect of which is to draw the barrel towards the cylinder breech and lock-frame as the key is pressed in; and pins, projecting from the end of the lock-frame, enter corresponding recesses in the bracket-piece of the barrel. The key *f* has a spring-catch, which rises when the key is forced "home," and, by its turned-up end coming in contact with the edge of the slot through which it has been passed, it will prevent the key from getting loose and shaking out of its place by the concussion of the firing. This object is further insured by the insertion in the barrel-piece of the screw 1, the head of which would come in contact with the turned-up end of the catch, if it had escaped past the edge of the slot, and prevent it from dropping, or even being drawn out; this screw must, therefore, be removed before the key can be displaced. Jointed to the bracket part of the barrel, by a pin 2, is a lever *g*, which is kept up in a position parallel to the barrel by a spring-catch at its other end taking into a catch on the lower side of the barrel. To this lever a plunger *h* is connected by a pin 3, taking into a slot on the outer end of the plunger. The inner end of the plunger slides in a guide made for it in the bracket-piece of the barrel. This plunger is intended to act as a ramrod, and to drive the bullets or cartridges into the several chambers of the breech, consecutively as they are brought in a line with the plunger.

To effect this the catch of the lever *g* is disengaged, and the lever is brought into the position shown by dots in Fig. 2222; the plunger is thereby driven forward and made to ram the bullet (which has been previously inserted in the end of the chamber, now brought in a line with the plunger) down into its proper place in the chamber; the plunger is then drawn back, and the next succeeding chamber brought in a line therewith, when the lever *g* is again brought into the dotted position, to thrust the plunger forward and ram down another charge; and thus successively all the charges are acted upon. By referring to the drawing, Fig. 2223, it will be seen that the mouths of the chambers and the inner end of the barrel are chamfered at their edges. This bevelling of the edges of the chambers is to prevent the lateral discharge between the breech and the barrel from igniting the powder in the other loaded chambers; for the ignited matter, by coming into contact with the bevelled edge as it crosses the mouths of the chambers, will be deflected outward and effectually thrown off, and be prevented from reaching the powder in the chambers. The bevelling of the end of the barrel is intended to prevent its cutting the ball in its passage from the chamber.

At Figs. 2226 and 2227 it will be seen that a hollow is made in one side of the shield *c**: the object of this is to expose the ends of the nipples as the breech is revolved, and thus to allow of the percussion

caps being readily placed thereon. The hammer a turns on a pin 4, in the lock-frame c; and it is provided with stops or catches for the end of the trigger to abut against, as usual, and hold it at whole or half-cock, as required. To the hammer is jointed a hand-catch i, with the spring k attached, Fig. 2222, which is pressed forward into contact with ratchet-teeth formed on the end of the breech, and allows the hand-catch to recede for passing below a second tooth of the ratchet. l is a rocking lever, supported by a pin in the lock-frame c, and carrying at one end a bolt, which is intended to enter, at certain times, into the recesses 5 5 in the periphery of the breech, a bearing-spring m, Fig. 2223, giving it always a tendency to rise for that purpose. The other end of this lever is made thin, so as to be capable of yielding laterally and recovering its position, thus allowing a stud 6 (which projects from the hammer and has a chamfered or bevelled face) to pass the lever without disturbing the position of the bolt-end when the hammer moves forward to fire the charge; and yet, when the hammer is drawn back, to present an obstruction to the stud 6, and be thereby tipped into the position shown at Fig. 2223, which movement will unlock the breech. As long as the hammer remains at half-cock the breech will be free to turn upon its spindle for the purpose of being loaded; but when the stud has passed the end of the lever, the spring m will again force the bolt of the lever into its original or locking position. The action



2224. 2225. 2221. 2222. 2226. 2229. 2228. 2227. 2223.

of drawing back the hammer to its furthest extent (the bolt being first relieved) will raise the hand-catch i, which, being brought in contact with a ratchet-tooth on the breech, will turn the breech round in the direction of the arrow, Fig. 2222, to the extent of one tooth, and thus bring up a loaded chamber in a line with the barrel; and, in succession, the act of cocking will bring all the loaded chambers in like manner round in a line with the barrel and hammer to be discharged. In order to insure the insertion of the bolt of the lever l into the recesses 5 5 as they severally come round, and thereby to hold the breech firmly while the discharge takes place, a shallow channel or guide is formed up to the edge of each, as shown in the figures, which will make the bolt feel its way to the recess and enter it more certainly than if it were required to fall into the recess suddenly. To prevent the fouling of the spindle and breech, a helical groove is formed upon the spindle, as shown at Fig 2223, the edges of

which will more effectually prevent the smoke from passing between the breech and spindle than if the whole periphery of the spindle were in contact with the breech; and at the same time these edges will, as the breech is rotated, scrape off any matters that may have become deposited in the central bore of the breech, and deposit it in the grooves. By this means the contact surfaces will be kept clean, and the breech, which would otherwise foul after a few discharges and become fixed, will be free to turn on its spindle, for a long period, without requiring any cleaning.

Fig. 2228 represents in side view, and Fig. 2229 in plan view, a rifle, carbine, musket, or shot-gun, with revolving breech. As the several improvements before described, with reference to the pistol, are equally applicable to guns for military and sporting purposes, the patentee gives merely a description of the modified arrangement of apparatus for ramming down the charges, as represented at Figs. 2228 and 2229. In this instance, instead of the plunger being applied below the barrel, it is attached to the side thereof. *a* is a bracket projecting from the side of the barrel, and to it the lever *b* is jointed by a pin 1. *c* is the plunger, having at about the middle of its length a joint 2; it is forked at one end, and embraces the lever *b*, to which it is jointed by a pin 3, and the cylindrical end of the plunger works between guide-pins 4 4 on the barrel. *d* is a spring-catch, riveted to the plunger *c*, and capable, when the lever *b* is laid parallel with the barrel, of taking into a notch cut in the bracket *a*. By means of this spring the ramming apparatus, when not required to be used, is retained in the position shown at Fig. 2228; but by drawing the lever *b* into the position shown at Fig. 2229, the catch will be immediately disengaged from the notch.

The patentee claims, First, making the lock-frame and recoil-shield in one and the same piece, whereby all possibility of the parts getting loose after repeated discharges is prevented. Secondly, the general arrangement of the lock and apparatus for turning and locking the rotating cylinder breech. Thirdly, the general arrangement of the parts, whereby the operations of loading and priming may be effected without disconnecting the breech, as was heretofore requisite. Fourthly, the application to guns and pistols of the lever apparatus for ramming down the charges into the several chambers with great expedition and effect—the same being a substitute for the loose ramrod. Fifthly, the chamfering the mouths of the chambers and the inner end of the barrel; also the grooving of the periphery of the breech-spindle; likewise the making sunk-guides to the locking recesses on the periphery of the breech; and, further, the means of insuring the proper position of the barrel with respect to the face of the breech.

GUN-COTTON. To Professor Schönbein, the entire credit is due of discovering and making known the various useful purposes to which gun-cotton may be applied, although its actual discovery dates from a period prior to that when Schönbein published his experiments.

In 1833, M. Braconnot observed, when starch was heated for a short time in strong nitric acid, until complete solution had been effected, and the solution was poured into a large quantity of cold water, that a white pulverulent amorphous substance gradually subsided, which, on being dried, was highly combustible, and burnt without leaving any residue. This substance was called xyloidine. M. Pelouze, in 1838, repeated the experiments of Braconnot, and found that paper, linen, cotton, and other ligneous substances, when submitted to the action of strong nitric acid, (sp. gr. 1·5,) for a few minutes, and then well washed with water and dried, possessed the same properties as xyloidine, without having lost, however, their original form and appearance. M. Pelouze was inclined to believe with chemists in general, that this was only another form of the same substance; he also threw out a surmise, that the substance might be applicable to certain useful purposes, especially in artillery. The same chemist, in conjunction with others, has, however, since shown, that these two substances are not identical. That the substance prepared by immersing paper, linen, cotton, &c., in nitric acid, contains more oxygen, and consequently more nitric acid than the xyloidine of Braconnot, and the name of pyroxyline or pyroxyle has consequently been given to it. The gun-cotton of Schönbein is probably this latter substance, or some body closely allied to it.

The plan adopted for the manufacture of this compound is as follows: cleansed cotton is immersed in a mixture composed of equal parts of concentrated nitric and sulphuric acids, or, according to Schönbein, of 3 parts sulphuric acid, and 1 of nitric acid, of sp. gr. 1·5, for about 10 to 15 minutes, and in order to prevent accidents, no portion of the cotton should be above the level of the liquid. The acid should then be pressed out, and the cotton which remains impregnated with it is well washed with water, until no acid reaction is perceptible to the tongue; it is now dried rapidly at a temperature not exceeding 212° F. Care should be taken, in drying this substance, to allow a free current of air to pass over it, and to spread out the cotton as much as possible, in order to prevent its forming into dense masses, which are much more liable to explode. It is, indeed, probable, that the method of drying in stoves, practised at first in Messrs. Hall's manufactory, was the cause of the explosion which occurred there, and which cost several persons their lives.

No minute description of the mode of preparing gun-cotton upon a manufacturing scale has been published up to this period, and the foregoing notice, which indicates the plan practised by M. Susane, at the *Direction des Poudres et Saltpêtres*, must suffice to give a general view of the process, which is no doubt carried out with slight differences, although the same in principle, in the different manufactories.

With regard to the composition of gun-cotton, nothing certain is established. The analyses which have been made of it, and which are numerous, do not accord, and tend rather to prove that several products may result from the action of nitro-sulphuric acid upon cotton, paper, &c., depending, amongst other things, upon the state of concentration of the acids used, the time of immersion, &c.

The properties of gun-cotton are very extraordinary, and create a greater degree of astonishment, in consequence of its outward appearance bearing the strictest resemblance to ordinary cotton wool, which, however, is not so harsh to the feel. It is insoluble in water both hot and cold, and when removed and dried, is found to have lost none of its original properties; acids have also no action upon it, and this effectually distinguishes it from xyloidine. The best solvent for gun-cotton is acetic ether, and this substance may be used for rendering it perfectly pure. It explodes violently when heated to 356° F., or

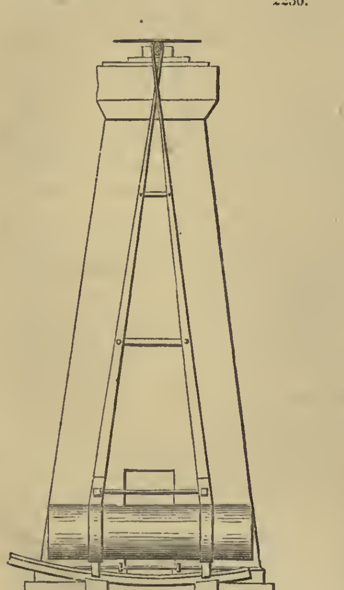
on ignition, leaving scarcely any residue, and creating very little smoke. The temperature at which it is thus decomposed, is so much below that at which gunpowder explodes, that the cotton may be lightly placed upon the surface of gunpowder, and detonized by a red-hot wire without setting fire to the powder. Friction of the ordinary kind will not explode gun-cotton, but when placed on an anvil, and powerfully struck with a hammer, the heat generated by the stroke causes it to detonate. With reference to the projectile force of gun-cotton, as compared with gunpowder, there appears reason to apprehend that its action, in its present form, is too rapid, and resembles too much that of the fulminates, to render it applicable to the purposes of artillery. The gaseous products from its combustion are also such as cannot be altogether resisted by fire-arms, although, if air be absent, no great amount of corrosion can ensue; and as it has been found that gun-cotton impregnated with chlorate of potash or nitre has a still more powerful effect than that prepared in the usual manner, the addition of these substances would at the same time tend to modify the corrosive action of the acid products of combustion. As a substitute for gunpowder in all mining and blasting operations, however, the superior local force of the powder-cotton will be highly valuable; and it has indeed been found to effect as much as four times its weight of powder. In the pyrotechnic art it will probably also be extensively used, and paper prepared by the method of Pelouze, and moistened with solutions of nitrate of strontia, sulphate of copper, and nitrate of baryta, yields very beautiful red, green, and white fires.

GUN METAL. A species of brass employed in casting cannon, and used also in the wearing parts or joints of machinery. This alloy should consist of 9 parts of copper and 1 of tin, but no zinc. It answers well for valves.

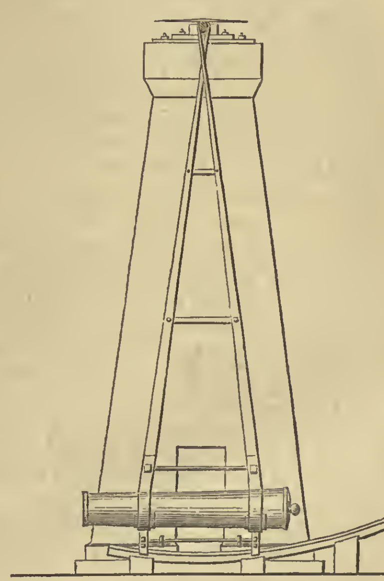
GUNPOWDER, *description of machines used in the proof of.* Cannon pendulum and its ballistic pendulum, of the Washington Arsenal, Figs. 2230 and 2231.

The pendulum-block.—The pendulum-block is of cast-iron, in the form of a hollow frustrum of a cone, with a hemispherical bottom. In order to give it the requisite strength, the block is closely hooped with wrought-iron over all the conical part, except in the places where it is embraced by the suspension straps; for this purpose the block was first turned, and the hoops were accurately reamed in a lathe, and then shrunk on to their places, using in this operation only heat enough to set the hoops closely to the cast-iron.

2230.



2231.



In order to facilitate the adjustment of the centre of oscillation of the pendulum, by throwing the weight as far as possible from the axis of motion, the block was made thicker on the lower side than on the upper, by placing the core of the hollow part above the centre of figure, thereby bringing the centre of gravity of the block 0·5 inch below its axis.

The opening in the face of the block is partially closed by an iron plate, which is held fast by bolts set in the block, and which serves to retain the sand used for filling the hollow of the block. In the centre of this plate is a circular opening 16 inches in diameter, through which the ball passes, and the point struck by the ball is marked by the hole made in a sheet of lead, (of about $3\frac{1}{2}$ lbs. to the square foot,) which is placed over the opening in the plate and retained by a washer, or smaller iron plate, bolted to the large one; vertical and horizontal scales, drawn on the face of the small plate, serve, by means of an easy reference, to measure the position of the point struck by the centre of the ball.

Manner of forming the core of the pendulum-block.—The hemispherical bottom of the core is formed of a block of lead, which serves to counterpoise the weight of the front part of the pendulum-block, and facilitates the adjustment of the axis in a horizontal position, by bringing the centre of gravity of the

system nearly in the middle point between the suspension straps; this lead forms also a sort of cushion to receive the impact of the balls, and to prevent them from striking against the cast-iron, in case they should penetrate through the sand which forms the chief part of the core of the pendulum-block.

The sand which receives the impact of the balls is contained in cases made of strong leather stretched over iron frames; the frame consists of two wrought-iron hoops, connected together by ribs of the same material; the diameter of each hoop is 0·75 inch less than that of the core, at the place which it is to occupy; each hoop is made in three segments, and the corresponding segments of the two hoops which form one frame, are connected together, each pair, by three ribs of square iron welded to the hoops. The leather which covers these frames is brought over the outer faces of the hoops and secured there by rivets, the sections of each hoop being connected together by the leather covering only. When the sand is compressed by the ball, the case or bag expands laterally, until it is supported by the sides of the pendulum-block.

The ends of these cases are closed with boards of soft wood, about ⅜ inch thick; those which form the bottom, or smaller end of the case, rest on iron pins which are set on the inside of the smaller hoop; and those which form the head, or larger end, are kept in place by small nails driven into wooden plugs in holes on the inside of the large hoop.

In order to fill the case or bag, it is placed on its small end, and the boards forming the bottom are laid down on the pins intended to support them; if there are any openings through which the sand might escape, they are closed with shavings, &c. The sand is then put in and settled with a small rammer, such as a piece of an implement staff; when nearly filled, the bag is placed on the platform of a balance, and its weight properly adjusted, after which the head is fastened in as before mentioned.

Four of these bags form a set for filling the pendulum-block: the first or smallest one is 15 inches high; the second, 14 inches; the third and fourth, each 12 inches; an interval of about 3 inches is thus left at the mouth of the block, which serves to admit any compensating weights that may be required to make up the proper charge. These weights are in the form of large rings, made of iron of different sizes, according to the weight required. The vacant space in the mouth of the block is requisite also for containing the sand displaced by the shot. A small portion of this sand escapes through the hole made by the ball in the sheet of lead on the face of the block.

The placing of the sand-bags in the block is facilitated by the use of a pair of large hooks, or tongs, attached to a tackle and fall, suspended from the roof of the pendulum-shed and hanging just in front of the block; when not in use they are drawn aside, out of the way of the pendulum, and hung on a hook driven into the frame of the shed.

Manner of suspending the pendulum-block.—The block is suspended by means of four straps of wrought-iron attached to a horizontal shaft of the same material.

The shaft terminates at each end in knife edges, made of hardened steel welded to the iron. These knife edges are rounded on a radius of 0·06 inch; inside of the knife edges, the shaft has cylindrical bearings which are turned with great care; the lower lines of the knife edges are in the surface of these cylinders produced, and consequently the axes of motion, at the two extremities of the shaft, are in the same right line.

The suspension straps terminate, at their upper ends, in collars which are accurately bored to fit the cylindrical bearings on the shaft. In the lower parts of these collars are *slots*, which fit on corresponding projections on the shaft and prevent the straps from turning; the collars of the straps are also pressed firmly, by means of keys, against the shoulders of the shaft. The two inner straps, from each end of the shaft, pass to the front end of the pendulum-block; the outer ones, to the rear end. The inner straps are straight, from the collars on the shaft to a point near the block where they take a direction perpendicular to the axis of the block, which they embrace between the shoulders provided for them. The outer straps are curved just below the shaft, so that at the distance of about 5 feet from the axis, the two straps from each end of the shaft are brought into the same plane, passing nearly through the axis of the block.

The work should be fitted together in such a manner that the line joining the centres of the two collars for the pendulum-block, which are thus formed by the two pairs of straps, shall be in a plane perpendicular to the axis of the shaft at its middle point, and shall be also perpendicular to a plane passing through the axis of the shaft and the middle point of the line in question, which line coincides with the axis of the block.

The pair of straps which embrace the front part of the block approach, above and below the block, within 8 inches of each other, and are kept apart by iron transoms which terminate at each end in bolts that pass through the straps, and are held by nuts on the outside. The other pair of straps come together within 2 inches, and the bolts which serve to press them against the block pass through the flattened heads of two large transverse bolts, the other ends of which are cut with a screw-thread. The ends of these bolts pass through holes in the transoms of the front pair of straps, and the bolts have strong screw-threads cut on their whole length, for a purpose which will be hereafter explained.

Between the pendulum-block and the shaft, the two straps from each end of the shaft are firmly connected together by two pairs of flat braces, having shoulders which bear against the edges of the straps; the upper braces are bolted to the straps, and they are connected together by a large cross-bolt which passes through the middle of each; the lower braces are connected with the straps, and with each other, by means of cross-bolts. All of these cross-bolts have bevel-washers against their shoulders inside, and under the nuts, outside of the braces.

Supports of the pendulum.—The knife edges of the shaft rest in V's formed in dies of hardened steel, which are set in cast-iron seats; these seats are bolted down to large cast-iron plates, resting on the tops of two stone piers, to which the plates are secured by long bolts let into the stone. On the upper sides of the plates there are projecting ledges, between which the seats for the V's are placed, and the position of these seats is regulated by means of wedges inserted between them and the projections on the plates. The bolt-holes in the seats are made of an oblong form, in order to admit of adjustment.

so that the two V's of each pair shall be in the same horizontal line, and that these lines, in the two pendulums, shall be parallel to each other.

The bottom parts of the V's are rounded on a radius 1-10th of an inch; and the inclination of the sides is so arranged, with reference to that of the planes of the knife edges, as to allow the pendulum to vibrate through an arc of 30°.

The parallelism of the two shafts is verified by means of two plumb-lines, suspended to the ends of a needle attached to each shaft in a direction perpendicular to its axis. Four other plumb-lines are suspended in the axis of the gun and block, (on the front and rear of each,) and when the adjustment is perfect, these eight plumb-lines should hang in the same plane.

Measurement of the arc of vibration.—The vibration of the pendulum is measured on a brass limb, placed under the axis of the block and supported by wrought-iron chairs set in stone posts. A slider, also of brass, moves on this limb, and is held at any point by the pressure of a light spring; the slider is moved by an index attached to a bar connected with the lower ends of the suspension straps. The limb is graduated in degrees and minutes, and the slider has a vernier which reads to two seconds. The *zero* of the arc is placed in the vertical plane passing through the axis of motion, and the face of the index is also in this plane when the axis of the block is horizontal, or situated in the line of fire. In order to have the means of verifying the adjustment of the limb, at any time, if necessary, two hollow centres are screwed into the under side of the shaft, near each end, for the purpose of suspending two plumb-lines that shall hang in the vertical plane through the axis of motion.

Gun pendulum.—The suspension-frame, the supports, and the general arrangement of the gun pendulum, are similar to those of the ballistic pendulum, and it is therefore necessary to describe only the manner of attaching the gun to the frame.

In order to provide for mounting guns of any calibre below a 32-pounder, the diameter of the circular parts of the suspension straps is sufficiently large to admit collars of cast-iron which may be adapted to the gun and made to fit on the trunnions, having shoulders to receive the straps; but the 32 and 24-pounder guns, heretofore attached to the pendulum, having been made for the purpose, the projecting pieces, to form the shoulders for the straps, were cast on the guns. In order to facilitate the adjustment of the centre of oscillation of the pendulum, and also to have a gun which shall be perfectly safe to use, with any charge up to ½ the weight of the shot, the 24-pounder has been made on the same model as the 32-pounder, and the trunnions are omitted, as the piece is designed for use with the pendulum exclusively.

Adjustment of the centre of gravity and of the centre of oscillation.—The two systems being nearly symmetrical, with reference to the vertical planes through the axis of motion and the axis of the gun or block, the centre of gravity of each pendulum was found nearly in the intersection of these vertical planes, when the axis of the gun or block is horizontal; it is therefore necessary to provide only for correcting the deviations caused by variations in the charge of the gun, or of the block. For this purpose, adjusting weights are placed on the large screw-bolts which connect the front and rear straps above and below the gun and the block; by sliding these weights backwards or forwards, the position of the vertical line containing the centre of gravity is easily adjusted. These weights effect another very important purpose, in the adjustment of the centre of oscillation of the system, so as to make it coincide with the axis of the gun or block.

The weight of the gun and block being very great, in comparison with that of the suspension-frame, the centres of oscillation were found to be nearly at the proper height, and the adjustment of them was readily effected by placing weights on the lower screw-bolt, which has the effect of lowering the centre of oscillation; the upper screw-bolt would be made use of in the same manner, in case the centre of oscillation should be found, by any change of circumstances, to be too low. These screw-bolts are flattened, or planed off, at the sides, in order to allow the weights to slide on them more readily. The weights are cylinders of various heights, having slits of the thickness of the screw-bolt, to facilitate placing and removing them. The slits are lined with thick sheet-iron to prevent the weight from being cut by the screw, and the height of the slit is so regulated (for convenience in calculation) as to bring the centre of gravity of the weight in the axis of the bolt on which it rests. The weights are made of lead, with about 6 per cent. of tin; they are moved on the bolt, and are also held in place, when set, by means of large nuts with handles, of which there are two on each bolt. To prevent these nuts from being pressed into the weights by their reaction in the recoil of the pendulum, broad iron washers are placed between the weights and the nuts, and the front weight for each pendulum is made of a shell of cast-iron ½ inch thick, filled with lead.

Weight of the pendulums.—The weight was ascertained to be as follows:—

	lbs.
Weight of gun-frame complete	2,811
" 32-pounder gun	7,689
Total of gun pendulum	10,500
" ballistic pendulum-frame complete	2,847
" pendulum-block, (empty)	6,368
" face-plates and bolts for do.	143
Total ballistic pendulum	9,358

Position of the centres of gravity of the pendulums.—The position of the centre of gravity of each system was determined by balancing the frame complete on the edge of a square steel bar, placed parallel to the axis of the shaft. The place of the centre of gravity of the gun and the block being known, that of the whole system is easily calculated.

The results of this calculation were verified by actually balancing, in a horizontal position, the whole pendulum, with the gun and block in place.

	Gun.	Block.
	Inches.	Inches.
Distance from the axis of motion to the centre of gravity of the frame.......	112·8	114·13
Distance to the centre of gravity of the gun or pendulum-block, (empty)......	195	195·5
Distance to centre of gravity of the system, (by calculation) $\dfrac{112{\cdot}8 \times 2811 + 195 \times 7689}{10{,}500} =$	172·994	
$\dfrac{2847 \times 114{\cdot}13 + 6368 \times 195{\cdot}5 + 143 \times 195}{9358}$ .... =	......	170·737
Distance to centre of gravity of the system, by trial.............................	172·8	170·8
Do. mean; taken as the true distance......................................	172·9	170·8

The height of the centre of gravity of each pendulum in this condition being known, it is easy to make the necessary correction for the addition of the adjusting weights, and for the weight of the core of the block. For this purpose it is sufficient to observe that the centre of gravity of the adjusting weights, being in the axis of the lower screw-bolts, is, in the gun pendulum, at 215 inches from the axis of motion, and in the ballistic pendulum, at 219 inches. The centre of gravity of the hemisphere of lead in the bottom of the pendulum-block is in the axis of the block, or 195 inches from the axis of motion; and that of the conical part of the core is 0·66 inch above the axis of the block, or 194·34 inches from the axis of motion.

In the gun pendulum, when adjusted for use with the 32-pounder gun, a weight of 667 pounds was placed on the lower screw-bolt.

In the ballistic pendulum there were

	lbs.
a hemisphere of lead in the block, weighing..	626½
an oak board over the lead..	9½
a sheet of lead on the face..	8
4 sand-bags..	965
adjusting weights on the lower screw-bolt..	789

Under these circumstances, the distance of the centre of gravity of the gun pendulum from the axis is

$$\frac{10{,}500 \times 172{\cdot}9 + 667 \times 215}{11{,}167} = \frac{1{,}958{,}963}{11{,}167} = 175{\cdot}41 \text{ in.},$$

and that of the centre of gravity of the ballistic pendulum,

$$\frac{9358 \times 170{\cdot}8 + 643 \times 195 + 975 \times 194{\cdot}34 + 789 \times 219}{11{,}756 \text{ lbs.}} = \frac{2{,}084{,}162{\cdot}5}{11{,}756} = 177{\cdot}29 \text{ in.}$$

The results of these calculations and measurements may be at any time verified, and in case of a change in the pendulums, they may be corrected, by practically ascertaining the moment of the system, i. e., the product of the weight into the distance of its centre of gravity from the axis of motion; and this moment is a factor which enters into the formula for the computation of the initial velocity of the ball. To ascertain the moment of the pendulum without dismounting it, it is sufficient to determine by trial the weight which, acting at a given distance from the axis, will sustain the system, out of a vertical position, at such an angle that the direction in which this weight acts shall be perpendicular to the line drawn from the centre of the axis of motion to the centre of gravity of the system. If a be the angle which this latter line then makes with the vertical, w the weight which balances the system, and d the distance at which it acts from the centre of motion, then will the moment of the pendulum be

$$\frac{w\,d}{\sin. a} = p g.$$

Position of the centre of oscillation.—The lengths of pendulums being to each other as the squares of the times of vibration, or inversely as the squares of the number of vibrations in a given time, the distance of the centre of oscillation from the axis of motion is determined by observing the number of vibrations made by the pendulum in any given time, or the number of seconds required for a given number of vibrations of the pendulum.

In the present instance this was determined by observing, with a chronometer which beats half seconds, the time required for 500 vibrations of the pendulum, commencing in an arc of about one degree and a half. The length of the seconds pendulum at Washington, (latitude 38° 53′ 23″,) being 39·1 in., the distance of the centre of oscillation of a pendulum vibrating 500 times in n seconds, will be

$$L = \frac{n^2 \times 39{\cdot}1}{500^2};$$

and in order that L shall be equal to 195 in., or that the centre of oscillation shall be in the line of fire of the pendulum-gun, n must be $= 1116{\cdot}5$ seconds.

In the gun pendulum, this adjustment of the time of vibration is effected by placing an additional weight of 667 lbs. on the lower screw-bolt, as above mentioned, in ascertaining the position of the centre of gravity. In the ballistic pendulum, when ready for use and loaded as above stated, the time required

for 500 vibrations is 1116 seconds, and the position of the centre of oscillation is at 194·8 in. from the axis.

When the position o' of the centre of oscillation is accurately ascertained, for any given condition of the system, the additional weight W, requisite to bring that centre into any other position, o may be computed very nearly by the formula

$$W = \frac{p\,g\,(o - o')}{d\,(d - o)},$$

$p\,g$ being the actual moment of the pendulum, and d the distance of the additional weight from the axis of motion.

In consequence of the lightness of the frames, in proportion to the whole weight of the pendulums, they are found to possess a great degree of sensibility; when vibrating in an arc of 14°, they lose about 36″ in one vibration; in an arc of 4°, about 25″. When set in motion in an arc of 12°, the gun pendulum continued to vibrate about 24 hours, and the pendulum-block (empty) about 30 hours.

Distance between the pendulums.—It was ascertained that, at the distance of 48 feet from the muzzle of the gun, the pendulum would be but slightly affected by the blast, and it was therefore determined to place the axes of the two pendulums 55 feet apart.

In order to intercept the blast of the gun as much as possible, a fixed screen of 2-inch oak plank is placed 17 feet in front of the face of the pendulum-block, having a hole in it 12 inches diameter for the passage of the ball. The protection afforded by this screen is such, that with a blank charge of ⅓ from the 32-pounder gun, the vibration of the pendulum-block does not exceed 45″; which vibration, if produced by the impact of a ball, would require a velocity of only 0·85 feet.

The penetration of the 32-pounder balls, in the sand of the pendulum-block, is about 4 feet. It is found that, in consequence of the great and sudden compression of the sand, produced by balls moving with great velocities, the penetration does not increase with the charge; but the pressure against the sides and bottom of the block is necessarily greater with higher charges, and under these circumstances, the mass of lead in the bottom of the block is so much compressed and battered as to make it inexpedient to fire with high charges (¼ or ⅓) from the 32-pounder gun, without filling the block with some material affording a greater resistance than sand.

Service of the pendulums.—Open all the doors and windows of the sheds; observe whether the nuts of the several connecting-bolts are screwed up tight, and whether the shoulders of the knife edges swing clear of the seats. Wipe out the V's and oil them with a small quantity of clear oil.

1st. *The ballistic pendulum.*—Load the pendulum-block with the sand-bags, driving them in with handspikes, so as to make them bear on each other; put on the face-plates with the sheet of lead previously adjusted between them.

Adjust, if requisite, the position of the centre of oscillation of the pendulum, and in order to maintain this adjustment, let the sand-bags be always filled to the same weight as at first. If this cannot be done, make up the correct total weight by placing some of the iron rings within the mouth of the block.

Wipe the graduated arc and move the adjusting weights on the lower screw-bolt, so that, the pendulum being at rest, its index shall be in contact with the slider when the latter stands at *zero;* in this position the axis of the block is horizontal: see that the nuts on the screw-bolts are set firmly against the adjusting weights.

After the gun is fired, two men stop the vibrations of the pendulum-block, checking them gradually with the hand, (or with a rope thrown over the breech,) and taking care not to displace the slider on the arc.

Note the arc of vibration.

Take off the face-plates and ascertain the position of the point struck by the centre of the ball, by referring the extremities of the vertical diameter of the hole made by the ball to the graduated scales on the outer plate. If necessary, note also the lateral deviation of the shot. Withdraw the sand and the ball, &c.; clean out the block with the rake and brush provided for the purpose.

2d. *The gun pendulum.*—The centre of oscillation is supposed to have been properly adjusted.

Wipe out the gun, insert the cartridge, push it home with the rammer, and measure the length which it occupies in the bore by means of the graduated brass scale set in the rammer-staff for that purpose; insert the shot, ram it home and measure in the same manner the height of the whole charge; prick the cartridge, and prime with a tube having a short piece of quick-match inserted in the cup, in order to give time for withdrawing the linstock before the gun recoils. A quill or paper tube is preferable for priming with, as the metal tubes are driven with considerable force against the sides, or the roof, of the shed.

Wipe the graduated arc and adjust the index of the pendulum as before, taking care that the nuts on the screw-bolt are set firmly against the adjusting weights.

Before giving the order to fire, be sure that both pendulums are at rest and in their true positions.

After the discharge, note the arc of recoil.

Two men stop the vibrations of the pendulum by throwing a rope over the breech of the gun against the suspension-frame; in this manner they are less apt to twist the frame than when acting directly with the hands against the gun. Clean out the gun and prepare for another charge. During the firings the pendulums should be carefully observed, to see if any derangement occurs in the position of the shafts in their V's, or in the stability of the frames, the tightness of the nuts, &c.

Formulæ for computing the velocity of the ball from the recoil of the pendulums.—1. *By the ballistic pendulum.*—The formula for the velocity with which the ball strikes the pendulum block is

$$v = \frac{2 \sin. \tfrac{1}{2} A \sqrt{(p\,g\,o + b i^2)\,(p\,g + b i)\,G}}{b i},$$

where v is the required velocity of the ball in a second;

p the weight of the pendulum;
g the distance of its centre of gravity
o the distance of its centre of oscillation } from the axis of motion;
i the distance of the point of impact
b the weight of the ball;
A the angle of first vibration of the pendulum;
G the measure of the force of gravity, $= 32{\cdot}155$ ft., at Washington.

The demonstration of the correctness of this formula is given in Hutton's Mathematical Tracts.

In our pendulums the axis of the gun and that of the pendulum-block are adjusted on the same horizontal line, when the pendulums are at rest; therefore the ball strikes very near to the axis of the block, and in order to prevent any shock on the axis of suspension, the centre of oscillation of the system is made to coincide also very nearly with the axis of the pendulum-block, and this adjustment is maintained by renewing the core of the block and restoring the pendulum after each shot to its original condition; hence the values of o and i in the above formula are very nearly equal, and the quantity $p\,g$ being very great in comparison with $b\,i$, no sensible error will be caused by assuming $i = o$ in the first term under the radical sign; the formula then becomes

$$v = 2 \sin. \tfrac{1}{2} A \frac{(p\,g + b\,i)\sqrt{G\,o}}{b\,i}$$

Moreover, in practice with balls of the same kind and calibre, the variations in the value of b are confined within narrow limits. On this account, and in consideration of the great inequality between the terms $p\,g$ and $b\,i$, we may, in the case just mentioned, assign to $b\,i$, in the numerator of the above expression, a constant value equal to the mean weight of the balls multiplied by the mean distances of the points struck from the axis of suspension. By this assumption the whole term $(p\,g + b\,i)\sqrt{G\,o}$ becomes constant for one set of experiments, and the formula is perfectly adapted to logarithmic computation.

In making the calculations of the velocity for a case of extreme variation in the value of $b\,i$, it was found that the error produced by the above transformation of the formula, and by assuming a constant mean value for $p\,g + b\,i$, is so small that it may safely be disregarded.

Since $2 \sin. \tfrac{1}{2} A =$ chord of A, it is obvious from the formula, that, all other circumstances being equal, the velocity of the ball is proportional to the chord of the arc of vibration of the pendulum.

2. *Computation of the velocity of the ball by the recoil of the gun pendulum.*—The formula for this purpose is taken from the Report of experiments on gunpowder at Metz. The formula is,

$$v' = \frac{2 \sin. \tfrac{1}{2} A' \dfrac{p'\,g'\sqrt{G\,o'}}{i'} - c\,N}{b' \dfrac{D^2}{d^2} + \dfrac{c'}{2}}; \text{ in which}$$

v' is the required initial velocity of the ball;
p' the weight of the gun pendulum;
g' the distance of its centre of gravity
o' the distance of its centre of oscillation } from the axis of suspension;
i' the distance of the axis of the gun
A' the angle of vibration of the pendulum;
b' the weight of the ball and wad;
D the diameter of the bore of the gun;
d the diameter of the ball;
c the weight of the charge of powder;
c' the weight of the cartridge, including the bag;
G the force of gravity, $= 32{\cdot}155$ ft.;
N a constant factor, of the same kind as g', G, &c., to be determined by experiment.

There are obvious causes of error and uncertainty which may prevent the results of this calculation of the velocity from coinciding in all cases with those obtained by means of the ballistic pendulum, even after allowance is made for the loss of velocity occasioned by the resistance of the air whilst the ball is passing from the gun to the pendulum-block. The principal one of these causes is the uncertainty of the value $\tfrac{1}{2} v'$, assumed for the mean velocity of the inflamed gunpowder in the bore of the gun. It is certain also that a considerable portion of the elastic fluid escapes through the windage of the ball, and therefore the mass of fluid behind the ball is less than that of the charge of powder; but this loss of fluid is in some measure compensated by the greater velocity of the part which passes by the ball. The effect now under consideration must likewise be modified by the quality of the gunpowder and the quantity of the charge, even within the usual limits of practice, and these circumstances probably exert a still greater influence on the value of the quantity N in the term $c\,N$. Capt. Mordecai found that the results of his experiments with the 32-pounder and 24-pounder guns were well represented by giving to N a mean value of 1600 feet. This value of N does not appear to apply equally well to the computation of the velocities of balls of very small calibre; for the intensity of the heat, and consequently the elastic force of the fluid, generated by the combustion of the charge, increase in a greater proportion than the direct ratio of the quantity of powder, and the value of N must therefore vary with the charge of powder, and also with the length and calibre of the gun and the density of the ball. However, as in ordinary practice with the cannon pendulum, the variations in the value of N cannot be great, and as the quantity $c\,N$ is much smaller in value than the other term in the numerator of the formula for the

velocity, no considerable error arises from assigning to that coefficient a constant mean value, as above stated.

Manner of loading the gun.—Of the balls.—The shot and shells used in these experiments were of an intermediate gage between the large and the small gage, *e. g.*:

For the 32-pounder gun, between 6·235 in. and 6·27 in.; and for the 24-pounder gun, between 5·66 in. and 5·70 in.

With the exception of some of the first 32-pounder shot, those used in the experiments were hammered shot. Each shot was floated in mercury, and the upper extremity of the axis passing through its centre of gravity was marked with a centre-punch. For the sake of brevity, the axis of the ball which passes through the centre of gravity will be designated as the *principal axis.*

Of the wads.—The wads ordinarily used in the experiments are *grommets*, or rings formed of a single strand of packing yarn, about $\frac{1}{2}$ inch thick, such as is used for the packing of pistons in machinery; this yarn is soft and very slightly twisted. The diameter of the grommet is a little less than that of the ball, to which it is attached by four leather straps about $\frac{3}{8}$ inch wide, each pair crossing the other at right angles, and being tied on the ball with twine strings; the grommet has also a cross of twine to assist in placing it and to preserve its form. The thickness of the leather straps is nearly equal to half the windage of the ball. The average weight of a grommet with straps is, for the 32-pounder ball, 0·1 lb.; for the 24-pounder, 0·08 lb.

The grommet is placed on the lighter hemisphere of the ball, in a direction perpendicular to its principal axis.

Of the cartridges.—The cartridge-bags are made of closely woven twilled woollen stuff; they are cut with a circular bottom like those for field service, and sewed on a cylindrical former of the regulation size, the diameter of the former being for the 32-pounder gun 5·9 in., and for the 24-pounder 5·35 in.

Of the manner of loading.—The cartridge being inserted, is pressed firmly with the rammer against the bottom of the bore, and its height measured. The ball is then placed with one of the leather straps resting on the lower side of the bore, the grommet outside, so that the heavier hemisphere of the ball is next to the powder. The leather straps not only retain the grommet, but also support the ball nearly in the centre of the bore.

In order to prevent the ball from being detached from the grommet, it was pushed to its place with the end of the rammer-staff, which caused it to slide on the bottom of the bore instead of rolling; the rammer being then turned, the height of the whole charge is measured. The difference between the height of the cartridge and that of the whole charge is less than the diameter of the ball, because the centre of the ball lies above the neck of the cartridge, and consequently the bottom of the ball passes beyond the tie of the cartridge and rests against the powder.

After the discharge the gun is cleaned with a cylindrical brush made of stiff bristles, and then wiped out with a common woollen sponge. The gun is washed after each series of rounds with the same powder, (generally after 3 rounds,) and is then wiped with a dry sponge.

The musket pendulum.—The frame for supporting the musket-barrel consists of two parallel bars of iron, connected together by a transom at each end; each of these bars has an ear containing a trunnion-hole to receive the trunnions of the musket-barrel, which are fitted into a solid cylinder of iron that is substituted for the breech-screw of the musket; the barrel is held in its place and adjusted by means of four set-screws passing horizontally through the bars of the frame, one pair near each end of it; a fifth set-screw, passing vertically through the front transom, serves to adjust the musket-barrel in a horizontal position when the frame is horizontal.

This frame is suspended by means of four iron rods, Fig. 2232; at the lower end of each rod is a shackle which is bolted to the transoms of the barrel-frame, and a similar shackle serves to connect the rods above with the shaft of the pendulum; the screws cut in the ends of each rod, to unite it with the shackles, are right and left hand screws respectively, so that by turning the rod, the distance of the frame from the shaft is increased or diminished at pleasure, and in this manner the height of the axis of the barrel is readily adjusted: when once adjusted, the rods are held fast by nuts screwed up against the shackles, to prevent the rods from turning.

The shaft of the pendulum is a flat bar of steel, at each end of which is a knife-edge well hardened and tempered.

The parts of this pendulum are so arranged that, when it is at rest, the frame is nearly horizontal; the slight adjustment requisite for making it exactly horizontal is effected by means of leaden weights, supported by a small bolt screwed into the rear transom of the frame; a thumb-screw nut serves to keep these weights in place, by pressing them up against the transom.

The knife-edges of the shaft rest in V's of hardened steel, which are set in cast-iron hangers connected by a plate, and this plate is secured by four bolts to another plate, also of cast-iron, which is firmly bolted and braced to a brick wall.

The arc of vibration is measured on a brass limb, which is clamped to an iron plate, on which it can slide in a circular direction, so that the zero of the limb may be properly adjusted; the iron plate is supported by a frame of wrought-iron secured to the wall, and furnished with four set-screws which serve to adjust the arc to the proper distance from the knife-edges; a slider moves in a groove in the brass limb, and is retained at any part of the limb by the pressure of a slight spring. In the vibration of the pendulum the slider is moved by an index attached to a bar which is fastened, at a suitable height, to two of the rods of the pendulum-frame.

The radius of the graduated arc is 57·3 inches; each degree of the brass limb is divided into six parts, and the vernier on the slider subdivides these parts into minutes.

The ballistic pendulum.—This pendulum is composed of a hollow conical block of bronze, suspended by two iron straps to a shaft formed of a flat bar of steel, with knife-edges like those of the musket pendulum; a brace between the straps serves to stiffen them, and into one end of this brace is screwed the index which moves the slider on the brass limb for measuring the vibration of the pendulum.

An iron clamp, of a simple construction, presses a circular wooden plate against the face of the pendulum, Fig. 2233, and the point struck by the ball is marked by the perforation of this wooden plate.

The core of the pendulum-block consists of, 1st. A block of hard wood, turned to fit the bottom part of the pendulum-block.

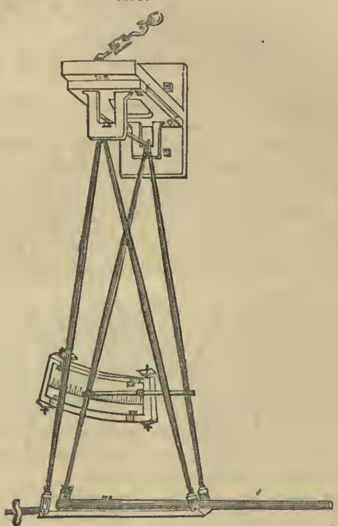
2d. A conical block of lead, faced with a plate of iron, occupying nearly the centre of the core.

3d. A block of hard wood, turned and cut to such a length as just to fill the pendulum-block, and to bear against the face-plate.

These blocks were made of well-seasoned hickory, accurately adjusted to the proper weight by boring holes in them, which were, when necessary, filled with plugs of lead. This weight is such as to keep the axis of the block horizontal when the pendulum is at rest.

The wooden face-plate was used for many rounds, the balls always striking in a hole one inch in diameter, in the centre of the plate.

2233.



2234.

The arrangements for suspending the ballistic pendulum and for measuring the vibration are the same as those for the musket pendulum. The distance between the axes of the two pendulums is ten feet; the muzzle of the musket is six feet from the face of the pendulum-block.

A screen of boards, having a hole two inches in diameter for the passage of the ball, is placed two feet in front of the ballistic pendulum, to intercept the wads and the blast of the charge.

The pendulums are attached to the south side of a brick wall, and covered by a wooden shed.

Service of the pendulums.—After numerous experiments on the manner of loading the musket-barrel, it was determined to adopt nearly the same method that is pursued in ordinary service.

The charges are weighed with an accurate balance and put into small tin canisters; to load the piece, the charge is poured into a small copper or tin charger attached to the end of a ramrod; the musket-barrel is inverted over it, the vent being previously stopped with a brass wire; the barrel and charger are then again reversed together, and the charge of powder is shaken out into the bottom of the barrel.

The ball is wrapped, as for a common cartridge, in a rectangle of ball-cartridge paper, 3 in. × 4·5; the paper is choked tight over the ball, and also slightly choked below, to prevent the ball from falling out. Instead of merely inserting the ball, with the paper, over the powder, the paper is first formed into a wad, in a manner nearly uniform, by putting the cartridge-case, with the paper down, into a piece of musket-barrel, and pressing on the ball with a wooden rammer, which crumples the paper neatly into a sort of sabot. In loading, the paper is inserted next to the powder; the ball is followed up with the rammer, which is of steel, and weighs 1½ pounds; this rammer is then raised six inches and let fall on the charge once: the height of the charge was always measured by a graduation on the rammer, in order to guard against error in loading.

The balls were prepared by means of dies, adapted to an ordinary punching machine, and were made very nearly exact in size, form, and weight.

After each discharge, the musket-barrel is taken from its frame, and wiped carefully with dry rags; it is washed generally after five rounds.

The set-screws on one side of the frame being undisturbed, the direction of the barrel requires no other adjustment, after being once set, than to be pressed up gently, but firmly, by means of the screws on the other side of the frame.

The charge is fired with a piece of quick-match in the vent.

The wooden block into which the ball is fired is 4·5 inches long; with a charge of even 100 grains the musket-ball generally penetrates through this block, (of hickory wood,) and is flattened against the iron plate with which the lead block is faced; the lead and the wooden core are usually wedged slightly against the sides of the block, and have to be driven out through a hole left in the bottom of the pendulum-block for that purpose.

Elements for computing the velocity of the ball.—The formulæ for this purpose are the same as those before given for the large pendulums.

The constant elements of the calculations, in the usual condition of the pendulums, are as follows:

1. *For the Ballistic Pendulum.*

Total weight of pendulum .... $p = 55$ lbs.
Distance of centre of gravity from knife-edges.................. $g = 61{\cdot}4$ in.
Time of 1000 oscillations............ ....1379 seconds.
Distance of centre of oscillation from knife-edges .... $o = 74{\cdot}354$
Force of gravity.. $G = 385{\cdot}86$
Distance of the axis of the block, or usual point of impact, from the knife-edges.. $i = 79{\cdot}$ in.
Weight of the ball of 0·64 inches diameter....................... $b = 0{\cdot}05679$ lbs.
do. do. 0·65 do. .... $= 0{\cdot}05861$

$$\text{Log. } \frac{2\sqrt{(pg+bi)(pgo+bi^2)G}}{12\,b\,i} \left\{ \begin{array}{ll} \text{for ball } 0{\cdot}64 \text{ in.......} & = 4{\cdot}3279424 \\ \text{for ball } 0{\cdot}65 \text{ in.......} & = 4{\cdot}3142795 \end{array} \right.$$

The variations in the point of impact being very small, its distance has been regarded as constant, in the denominator as well as in the numerator of the formula; but in case of any considerable variation the correction is easily made in the above logarithms, by adding or subtracting, as the case may be, the difference between the logarithm of 79 and that of the true value of i.

2. *For the Musket Pendulum.*

Total weight of pendulum .... $p' = 88{\cdot}94$ lbs.
Distance of centre of gravity from knife-edges...................... $g' = 43{\cdot}85$ in.
Time of 1000 oscillations.............................. 1297 seconds.
Distance of centre of oscillation from knife-edges.................. $o' = 65{\cdot}77$
Force of gravity.. $G = 385{\cdot}86$
Distance of axis of barrel from knife-edges .... $i' = 79{\cdot}$

$$\text{Log. } \frac{2\,p'\,g'\sqrt{G\,o'}}{12\,i'} = 3{\cdot}1175821$$

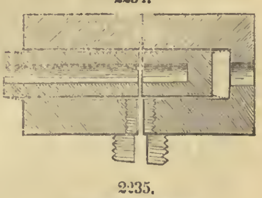
Mean weight of the rectangle of cartridge paper, (3 in. × 4·5 in.) in which the ball is wrapped .... 10·5 grs.
Diameter of the bore of the musket-barrel .... 0·69 in.

No value that can be assigned to the quantity N in the formula will produce results of equal accuracy when applied to different kinds of gunpowder, and in all cases it appears that the value of N is much smaller for the musket than for the cannon pendulum. This would appear to be the natural consequence of variations in the force or intensity of the flame produced by the combustion of various kinds of powder; that powder which acts with the greatest force on the ball whilst it is near the bottom of the musket-barrel, having been more thoroughly consumed at the first moment of ignition, will probably have a smaller proportional expansive force remaining, after the ball has left the barrel, than the powder, which, burning with less energy at first, continues to develop its force as the ball passes through the barrel; and this difference of effect becomes greater in proportion as the length of the barrel is increased, and the absolute quantity of powder in the charge diminished.

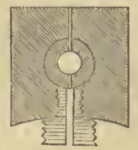
The apparatus for closing the vent was suggested by that proposed for Mr. Colson's eprouvette, in the fourth number of the "*Mémorial de l'Artillerie.*"

The apparatus is represented in Figs. 2234 and 2235; it consists of a block of wrought-iron, hollowed out on the under part to fit the gun, and having a small hole through it to correspond with the vent of the gun when the block is in place; this block is bored longitudinally, to receive a hollow conical plug of cast-steel, which is ground to fit tight in its place when pushed down to the bottom of the bore in the block; the plug has also a transverse hole, or vent, through it, which corresponds with that in the block when the plug is drawn out about 0·4 inches from the bottom of its lodgment in the block, so that, in that position, there is a direct communication open with the bore of the gun. The hollow plug is charged with a small quantity of fine, quick (sporting) powder, over which a paper wad is rammed; it is then placed in the position above described, and the charge is fired by means of a small piece of quick-match inserted in the upper part of the vent in the iron block; the charge in the gun is ignited with certainty, although there is no priming in the proper vent of the piece; but before the explosion of the charge, the conical plug has recoiled to the bottom of its lodgment, and effectually closed the vent.

2234.



2235.



After the discharge the plug is again driven out, through a hole made for the purpose in the bottom of the iron block; the plug should be fitted so as to bear against the bottom at nearly the same time that it becomes wedged in its seat, otherwise too great a force is required to drive it out; on the other hand, if the plug touches the bottom before it binds on the sides, it will fly out again, and not produce the desired effect.

Conclusions.—The following are some of the practical conclusions which Capt. Mordecai has arrived at by his experiments at the Washington Arsenal.

With regard to the proof of gunpowder.—The only reliable mode of proving the strength of gunpow

der is to test it, with service charges, in the arms for which it is designed; for which purpose the ballistic pendulums are perfectly adapted.

Although the present tendency to the use of cannon of very large calibre would make the proof by means of a 32-pounder or 24-pounder gun more satisfactory than by using a piece of smaller calibre, it does not seem to be necessary to resort to those heavy guns for obtaining a correct indication of the relative force of different kinds of powder. Such an indication is not given by a 1-pounder gun; but the experiments at Metz have shown that the 12-pounder gun classes the powders in the same order of strength as the 24-pounder; and further experiments may, perhaps, prove that a long gun of yet smaller calibre, a 9-pounder or a 6-pounder, will give corresponding results. I should propose, for the usual proof of gunpowder, to make use of the cannon pendulum alone; employing a gun of the smallest calibre which will give correct results, and firing the balls into a bank of earth, which would not make them unfit for ordinary service.

In the 24-pounder gun, new cannon powder should give, with a charge of ¼th, an initial velocity of not less than 1600 feet to a ball of medium weight and windage.

For the proof of powder for small arms, the small ballistic pendulum is a simple, convenient, and accurate instrument. The cost of the apparatus might be reduced by dispensing, in most cases, with the musket pendulum, and simply firing the ball into the ballistic pendulum-block, from a barrel set in a permanent frame.

The initial velocity of the musket-ball, of 0·05 inches windage, with a charge of 120 grains, should be.

With new musket powder, not less than 1500 feet;

With new rifle powder, not less than 1600 feet;

With fine sporting powder, not less than 1800 feet.

The common eprouvettes are of no value as instruments for determining the relative force of different kinds of gunpowder.

Of the hygrometric test of gunpowder.—Although the projectile force of gunpowder is the most important quality to be attended to in the proof and inspection, its capability of being long preserved without much deterioration, and of resisting the effects of such exposure as it is subject to in service, must be regarded as of little less importance. This quality should, therefore, be tested either by comparing the quantity of moisture absorbed, under similar circumstances, by the powder which may be under trial, and by other powder of approved good quality, or by the application of a simple chemical test of the purity of the saltpetre, as it is on this circumstance chiefly that the capacity of the powder to resist the action of a moderate degree of moisture depends.

Of the proportions of the ingredients of gunpowder.—The proportions used in making our best powder, 76—14—10, and the English proportions, 75—15—10, appear to be favorable to the strength of powder, and not sensibly disadvantageous in other respects; but the ordinary variations in the proportions of cannon powder are scarcely appreciable by their effects on its force.

Of the mode of manufacture.—The powder of greatest force, whether for cannon or small arms, is produced by incorporation in the "cylinder mills," under heavy rollers. In this manufacture, the essential operations are the separate pulverization of the materials, their incorporation by the cylinder mills alone, and the formation into cake by moderate pressure, on thick cakes. The time of running the mills on a given charge must depend partly on the weight of the rollers; but the diminution of this time by means of previous mixture of the ingredients for several hours, in the dust-barrels, appears to impart to the powder a degree of density which, although attended, perhaps, with somewhat increased force in the cannon, is injurious to other valuable qualities of the powder, and especially to its capability of resisting the effects of exposure to moisture.

The pounding mill is capable of producing powder of nearly equal force to the cylinder-mill powder, but for that purpose it must be worked not less than 14 or 16 hours, and even then, unless it is pressed, the grain is hardly sufficiently firm to bear, without injury, the jolting of ammunition wagons.

Of the density of gunpowder.—The density should not be *less* than 850; it is not easy, and perhaps not necessary, to establish an absolute *maximum* of density, on account of the differences caused by accidental variations in the size and form of the grains; but it does not appear necessary or advisable that the gravimetric density should exceed 920.

Of the sizes of grain for gunpowder.—If it should not be deemed incompatible with the convenience of service to multiply the varieties of powder for special purposes, there would probably be an advantage in using very large-grained powder (such as that designated by A. 0) for 13-inch mortars, and for the heavy sea-coast howitzers, in which enormous charges of powder are used. By this means the strain on the gun would be diminished, and the velocity of the ball perhaps increased.

For *musket powder*, by the present standard gages—

All the grains should pass through No. 4;

About one-half through No. 5;

Nearly one-fourth through No. 6.

This would give about 2000 or 2500 grains of powder in 10 grains Troy.

For *rifle powder*, all the grains should pass through No. 6. There would then be about 12,000 or 15,000 grains of powder in 10 grains Troy.

Of the charges for cannon and small arms.—For *cannon*, the charge of ¼th the weight of the ball, with powder of the standard strength proposed, impresses on the ball a sufficient velocity for all the ordinary purposes of service. For any purpose, even for a breaching battery, the advantage gained by using a charge greater than ⅓d the weight of the ball is unimportant, and by no means compensates for the inconvenient recoil, and the destructive strain on the gun and carriage, &c.

But as the habitual charge in the French and other services is ⅓d, and the battering charge ½ the weight of the ball, it may be well to compare the effects of these charges of French powder with that of the charges which Capt. Mordecai proposes to substitute for them. For this comparison a glance at the following table will suffice.

The French 30-pounder corresponds very nearly, in diameter and length of bore, with our 32-pounder. The windage of the balls used in the French experiments is somewhat greater than that of the balls used in Capt. M.'s experiments, but the difference is not very important.

Place of experiment.	Calibre of gun.	Kind of powder.	Charge.	Velocity of ball at the pendulum.	Remarks.
				Feet.	
Esquerdes	30-pound.	French pounding mill	$\frac{1}{3}$	1513	Mean with 4 kinds of powder.
Washington Arsenal	32-pound.	a. Cylinder mill	$\frac{1}{4}$	1535	
		A. Cylinder mill	$\frac{1}{4}$	1611	
Esquerdes	24-pound.	French pounding mill, 11 hours	$\frac{1}{3}$	1677	Mean of 40 rounds, with 2 kinds powder.
Metz	"	French pounding mill, 11 hours	$\frac{1}{3}$	1575	Powd. made at Metz, 1836.
Washington Arsenal	"	a.	$\frac{1}{4}$	1570	
		A.	$\frac{1}{4}$	1687	
Metz	24-pound.	French pounding mill	$\frac{1}{2}$	1772	Ditto.
Washington	"	A.	$\frac{1}{3}$	1833	

For small arms the following charges are proposed:
For the *percussion musket*, with the proposed musket powder, 110 grains.
For the *percussion rifle*, 75 grains.
For the *percussion pistol*, 30 grains of rifle powder.

Of cartridges for cannon.—For the purpose of diminishing the strain on the gun, Capt. M. proposes that the principle of increasing the length of the cartridge, by reducing its diameter, should be adopted for heavy guns. The diameters of the cartridge formers may be established as follows:

Calibre	42	32	24	18
Diameter of cartridge former............ Inches	6·	5·5	5·	4·6

Of the loss of force by windage.—Bring the results into one view, as in the following table:

Calibre of gun.	Powder of one kind.	Ball.		Differences.		Ratio of difference.	
	Weight.	Windage.	Velocity.	Of windage.	Of velocity.	Of windage.	Of velocity.
	Lbs.	Inch.	Feet.	Inch.	Feet.		
24-pound.	"	0·007	1578				
"	"	·115	1459	0·108	119		
"	"	·245	1332	·238	246	2·28	2·07
"	"	·355	1197	·348	381	3·22	3·20
"	6	·115	1749				
"	"	·245	1596	0·13	153		
"	"	·355	1465	·24	284	1·85	1·86

By taking the difference between the first windage and each of the others, in each set of experiments, and the corresponding differences of velocity, and then dividing each of these differences by the first of its series, we obtain the ratios between the several differences of windage, and between the corresponding differences of velocity. These ratios approach so nearly to equality as to authorize the conclusion that the differences in the velocities of balls of different diameters are proportional to the differences of windage; or, in other words, that *the loss of velocity by windage is proportional to the windage.*

Of the loss of force by the vent of the gun.—The loss of velocity in consequence of the escape of gas through the vent of a cannon is inappreciable, in comparison with the unavoidable variations produced by other causes: so far as this effect is concerned, it would be nearly useless to close the vent in firing the gun.

Of the effect of wads.—In the service of *cannon*, heavy wads over the ball are, in all respects, injurious. For the purpose of retaining the ball in its place, light *grommets* should be substituted for junk or hay wads, and the latter should be used only for proving guns, for firing hot shot, or for saving the bore of the gun from injury by placing them between the powder and ball, in order to change the seat of the ball, from time to time, and prevent the formation of a *lodgment.*

In *small arms*, on the other hand, it is of great importance, for developing the full force of the charge, that there should be a good wad over the powder, unless the ball has but very little windage, as in the rifle.

GUNTER'S CHAIN, so called from its reputed inventor, is the chain commonly used for measuring land. It is 66 feet or 4 poles in length, and is divided into 100 links, each of which is joined to the adjacent one by three rings; and the length of each link, including the connecting rings, is 7·92 inches

The advantage of this measure consists in the facility which it affords to numerical calculation. The English acre contains 4840 square yards; and Gunter's chain being 22 yards in length, the square of which is 484, it follows that a *square chain* is exactly the tenth part of an acre. A square chain again contains 10,000 square links, so that 100,000 square links are equal to an acre; consequently, the contents of a field being cast up in square links, it is only necessary to divide by 100,000, or to cut off the last five figures, to obtain the contents expressed in acres.

GUNTER'S LINE. A logarithmic line engraved on scales, sectors, &c., serving to perform the multiplication and division of numbers instrumentally, as a table of logarithms does arithmetically. The numbers are usually drawn on two separate rulers sliding against each other. In rough calculations this line affords considerable facilities.

GUNTER'S SCALE is a large plain scale, having various lines of numbers engraved on it, by means of which questions in navigation are resolved with the aid of a pair of compasses. On one side of the scale the natural lines (as the line of chords, the line of sines, tangents, rhombs, &c.) are placed, on the other the corresponding logarithmic ones.

GUTTA PERCHA, or, more properly, Gutta Tuban, is the concrete juice of a tropical tree, and is drawn, at certain seasons of the year, like the sap of the sugar-maple, by tapping the tree.

The mode in which the natives obtain the gutta is by cutting down the trees of full growth and ringing the bark at distances of about twelve to eighteen inches apart, and placing a cocoanut-shell, spathe of a palm, or such like receptacle, under the fallen trunk to receive the milky sap that immediately exudes upon every fresh incision. This sap is collected in bamboos, taken to their houses, and boiled in order to drive off the watery particles and inspissate it to the consistence it finally assumes. Although the process of boiling appears necessary when the gutta is collected in large quantity, if a tree be freshly wounded, a small quantity allowed to exude, and it be collected and moulded in the hand, it will consolidate perfectly in a few minutes, and have all the appearance of the prepared article.

When it is quite pure the color is of a grayish white, but as brought to market it is more ordinarily found of a reddish hue, arising from chips of bark that fall into the sap in the act of making the incisions, and which yield their color to it. The great peculiarity of this substance, and that which makes it so eminently useful for many purposes, is the effect of boiling water upon it. When immersed for a few minutes in water above 150° Fah., it becomes soft and plastic, so as to be capable of being moulded to any required shape or form, which it retains upon cooling, and regains its original toughness and flexibility.

The gutta percha is soluble, but not by the same agents as India-rubber. The fixed oils are all unctuous substances, and acids have no influence upon it. This property renders it very valuable for purposes of machinery, where, when used for driving-bands, as it is most extensively, it is constantly brought in contact with oils and grease.

Gutta percha may be manufactured by "moulding, stamping, embossing, casting, or any other known process or processes, into various articles of use; as glass and picture frames, cornices, mouldings, and other architectural ornaments, panelling, mosaics, &c.;" in a word, it may be worked into any form, and almost any color may be given, from the simplest to the most complex. Cornices of the most elaborate designs, in imitation of several kinds of wood, are manufactured of it; and from the toughness of the material, even the most delicate representations of foliage are not liable to injury. Copies of old oak panelling taken in the gutta percha, have preserved every trace of the original; the grain of the wood, its abrasion by age, its color and pattern, and all with the utmost fidelity. Impressions taken from coins and medallions are really beautiful; and statues may be copied by it with great truth and at a comparatively small cost.

Its capabilities of application to so many of the staple articles of our country, aside from its employment in the department of the ornamental arts, gives to its manufacture an almost boundless extent. Something may be judged of the truth of this statement by running the eye over the following list of articles, which by no means exhausts the range of gutta percha:

Machine belts and bands; gas-pipes and water-pipes; speaking-pipes; the insulating of telegraph wires; saddles and harness of all kinds; trays, fancy boxes, tables, pumps, boxes, and valves; book-binding, vellum, balls, water-proof roofing, inkstands, drinking-cups, canes, whips, flasks, hats, caps, boots, shoes, clothing; decorations for houses and ship-cabins; chairs; lining for bread casks for sea voyages; air-tight coffins; linings for water-tanks; powder kegs, for the transportation of powder in water; soda fountains, gasometers, bottles, pictures, and looking-glass frames.

It also recommends itself to the attention of the medical faculty; and as scientific persons give the subject the attention that humanity demands, it will be found to possess valuable properties, superior for many purposes to any other substance. It has already been approved for bougies, catheters, stethoscopes, nipple-shells, bandages, and splints. This latter article is invaluable from the facility with which it adapts itself, when made plastic in boiling water, to the form of the limb; for preserving the strength of medicines of a volatile nature, and in the application of galvanism or electricity to the healing art, it can be made a valuable agent, being a perfect non-conductor. For marine and national purposes, the field is most extensive; as an inside sheathing for ships, for buoys, and beacons, it is supposed to resist for all time the vermin that is so destructive in southern waters. Army and navy equipments, canvas, deck-covers, car-covers, sails, and rigging, are rendered impervious to water and dampness, preventing mildew and rot. It is of a light color, and not injured by climate or a tropical sun. For cannon-covers, water-tanks, *life-boats*, and many other applications, it is destined to supersede metal and India-rubber. It will also be found superior to glue in its adhesive properties, and to the gums generally, as a basis for various varnishes, sizings and paints, being weather-proof and not liable to crack.

Gutta percha is a perfect non-conductor of electricity, and, as above stated, is used for the insulating of telegraph wires; in Prussia the wires are covered with the gutta and embedded in the earth, and afford by far the best and surest means of preserving telegraphic communication.

Various experiments have been made to ascertain its strength when mixed with other matters and

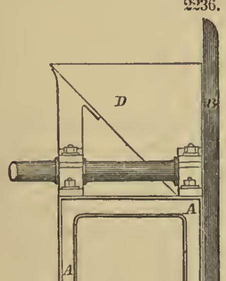
also as to what pigments would mix with it without rendering it brittle or deteriorating its qualities From these it appeared that the only pigments that could altogether be relied on to be used with gutta percha, were orange lead, rose pink, red-lead, vermilion, Dutch pink, yellow ochre, and orange chrome. Under the influence of heat and pressure, gutta percha would spread to a certain extent, and more so if mixed with foreign matters. All the mixtures composed of gutta percha and other substances which had been subjected to experiment, except that containing plumbago, were found to increase its power of conducting heat; but in its pure state gutta percha was an excellent non-conductor of electricity. The best composition for increasing the pliability of gutta percha was that formed in conjunction with caoutchouc tar, and next in order that of its own tar; and the best material at present known for moulding and embodying was obtained by mixing gutta percha with its own tar and lamp-black. Driving-bands for machinery are thus made, and shoe soles and heels are stamped out of similar sheets of gutta percha. In making tubes or pipes of gutta percha or any of its compounds, a mass of gutta percha, after being thoroughly masticated, is placed in a metal cylinder furnished with a similar piston, by which it is pressed down into an air-box, kept hot with steam, which has at its lower end a number of perforations, through which the plastic material is forced into a cup, whence it passes out, round a core, into the desired tubular form, and thence through a gage to the required size, and into a receiver of cold water, being drawn to the other end of a long trough by a cord passing round a pulley at the far end of the trough, and returning to the person in attendance on the machine, who gradually draws the pipe away from the air machine. Thus tubes of considerable length and diameter are made to a very great extent, and are used for the conveyance of water, liquids, and gas.

The machinery for working the crude gutta percha is constructed and worked as follows:

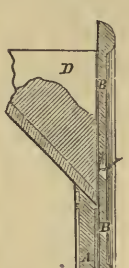
Fig. 2236 is a side elevation of the slicing machine; Fig. 2237 a front elevation of it; and Fig. 2238 a sectional elevation A on the line $a\,b$ of Fig. 2237.

A A represents the frame-work; B is a circular iron plate, of about five feet diameter, in which are three slots, into which are inserted three radial knives, in a similar manner to the irons of an ordinary plane or spoke-shave. B^2 is a shaft, to the end of which the plate B is attached, and by means of which it is made to revolve at any desired velocity, motion being communicated to the shaft from a steam-engine, or any other convenient first mover, through the medium of geering or drums. D is an inclined shoot, down which the lumps of crude gutta percha are dropped against the knives of the revolving plate B, by which they are cut into slices of a thickness corresponding to the degree of projection given to the knives. The slices are afterwards collected, and put into a vessel filled with hot water, where they are left to soak till they feel soft and pliable to the touch.

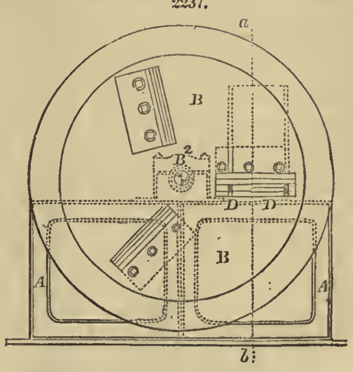
2236.



2238.



2237.

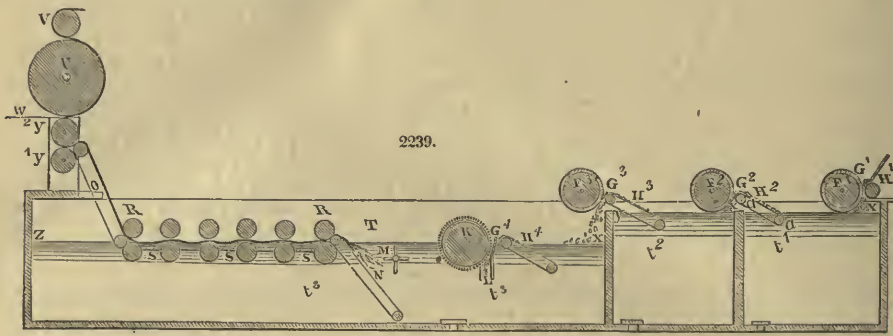


The knives are represented in the drawings as being straight; but where the gutta percha to be cut happens to be of a more than usually hard or intractable quality, it is advantageous to substitute knives of a curved or reaping-hook form, on account of their more gradual mode of action.

Fig. 2239 is a longitudinal elevation in section of the machinery through which the gutta percha is passed, after having been steeped as aforesaid in the hot-water vessel till it has become soft and pliable to the touch. T is a large tank, which is divided into three compartments $t^1\,t^2\,t^3$, of which t^1 and t^2 are filled with water to the height of the line $x\,y$, and t^3 with water to the height of the line $x\,z$. $F^1\,F^2\,F^3$ are three breakers or rollers, with serrated blades inserted in them in a direction parallel to their length, which are mounted transversely over the tank T, and revolve clear of the water. In front of each of these breakers there is a pair of fluted feeding-rollers $G^1\,G^2\,G^3$. H^1 is a funnel-shaped shoot, through which the softened pieces of gutta percha, after being taken from the hot-water vessel, are passed to the feeding-rollers G^1 of the first breaker F^1. H^2 is an inclined endless web, which revolves on two rollers $a\,a$, and dips at its lower end into the water, while at its upper end it comes opposite the space between the feeding-rollers of the breaker F^2. H^3 is a second inclined endless web, which bears the same relation to the third breaker F^3 as H^2 to F^2. K is a mincing cylinder, with radial blades (similar to that used in paper-mills for the conversion of rags into pulp) which is mounted transversely over the third compartment t^3 of the tank, but at a lower elevation than the breakers $F^1\,F^2\,F^3$, so that one-half of it shall always be immersed in the water in that compartment. L is an edge-plate, so fixed that the blades of the cylinder K shall, in revolving, come into such close parallelism with it, as to produce, by their approximate conjunction, a scissor-like sort of action on any matters which may come in contact with it. The mincing-cylinder K has, like the breakers $F^1\,F^2\,F^3$, an endless web H^4, and a pair of feeding-rollers G^4 attached to it. M is a rotary agitator, which is wholly immersed in the water

of the compartment t^3. N is a revolving endless web, which stretches in an inclined direction athwart the whole depth of the water in t^3, and subdivides (as it were) the compartment t^3 into two divisions. R R, R R, are a series of pairs of rollers, mounted transversely over the after part of the compartment t^3, at such an elevation that the under rollers revolve under the water, and the upper just free of it. S S are a series of tables or benches, placed between the pairs of rollers, for the purpose of supporting the gutta percha in its passage from one to the other

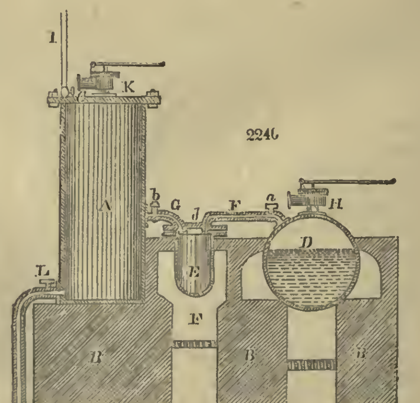
2239.



The action of this machinery, so far as it has been thus described, is as follows:

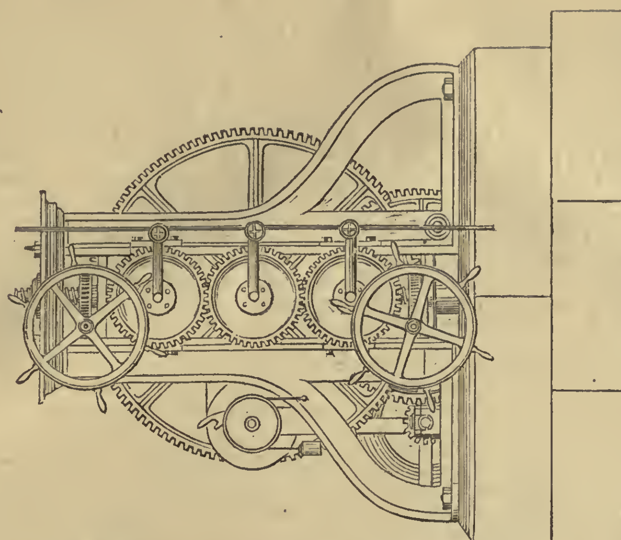
The feeding-rollers G^1 G^2 G^3 G^4, the carrying-rollers of the endless webs H^2 H^3 and H^4, and the rollers R R, are all made to revolve in a forward direction, or from left to right of the machine, as represented in Fig. 2239, while the breakers F^1 F^2 F^3, the mincing-cylinder K, and agitator M are made to revolve in the opposite direction. (The mechanical contrivances by which these movements are affected are omitted from the figure, as being all of a common and well-understood description.) The breakers and mincing-cylinder should revolve at the rate of from 600 to 800 revolutions a minute, but the feeding-rollers and endless webs need not move faster than at about a sixth of that rate. The first series of rollers R R should revolve at the rate of from fifteen to twenty revolutions per minute, and the others may be made to exert a drawing or stretching effect on the materials passed between them, by causing one, two, or more of the last pairs in the series to revolve at a greater velocity than the preceding ones. As the crude gutta percha is presented by the feeding-rollers G^1 to the action of the first breaker F^1, it is broken up into shreds or fragments, and considerable quantities of earthy and other extraneous matters are beaten out of and disengaged from it, the whole falling in a mingled mass into the water beneath, (that, viz. which is contained in the compartment t^1 of the tank,) where the different materials assort themselves according to their specific gravities. Such pieces as consist of pure gutta percha, or in which gutta percha predominates, float on the surface of the water, while most of the earthy and other extraneous matters sink to the bottom. The revolving endless web H^2 then draws towards it the floating gutta percha, and carries it upwards to the second set of feeding-rollers G^2, mounted over the second compartment t^2 of the tank, from which rollers it is delivered to the second breaker F^2, to undergo a repetition of the process which has been just described, in order to its being further disentangled and purified. From the surface of the water in the compartment t^2, the gutta percha is carried up the inclined endless web H^3 to the rollers G^3, which deliver it to the third breaker F^3 over the compartment t^3, by which it is a third time broken up, in order to any remaining impurities being separated from it. The inclined endless web H^4 next carries it forward to the rollers G^4, which present it to the revolving cylinder K, by the blades of which it is cut or minced into a multitude of very thin slivers, which, as they fall into the water in t^3, are thrown forward in the direction of the agitator M. As this agitator revolves in a direction opposite to that in which the floating mass of gutta percha is moving, it forces the gutta percha down into the water, and to take a circuitous course through it towards the large endless web N, whereby it is washed free from any dirt which may have collected upon it in passing through the preceding operations. By the endless web N, the gutta percha is next moved onwards to the series of rollers R R, R R; and from the last pair of the series, the gutta percha is raised by an endless revolving web O to a pair of metal pressing and finishing rollers Y^1 Y^2, which are set by adjusting screws to a distance from one another equal to the thickness of the sheet or band into which it is now desired that the gutta percha should be compressed. After passing through between Y^1 Y^2, the sheet or band is carried back over the topmost of these rollers Y^2, and then over the wooden drum U, to be wound on a taking-up roller V. As it is turning back over the roller Y^2, a sheet of cloth, or any other material suitable for joining with it, may be led in, as shown at W, and, by being pressed in conjunction with it between Y^2 and the drum U, it will be firmly united to it.

2240

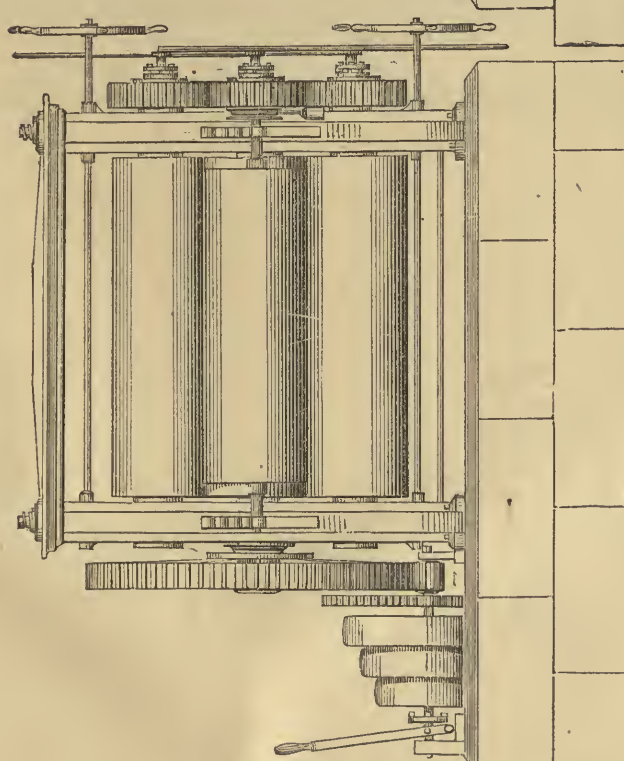


The water in all the compartments of the tank T should be used cold. When the crude gutta percha happens to have a fœtid smell, as is not unfrequently the case, mix with the water a solution of common soda, or of chloride of lime.

2242.



2241.



In effecting the combination of sulphur and sulphurets with gutta percha, expose the gutta percha, after it has been cleansed and purified and reduced to a sheet state, to the combined action of steam of a high temperature, and the vapors of orpiment (or other volatile sulphuret) and sulphur, (mixed in the proportions last hereinbefore specified,) in an apparatus of the description represented in Fig. 2240.

A is a strong metallic chamber set in the brick-work B B, into which the materials to be sulphu-

retted are placed. C is a steam-tight cover or door, which is secured to the top of the chamber by screw bolts, so that it may be unscrewed and removed as occasion may require. D is a common high-pressure steam-boiler. E is a strong metal pot into which the orpiment, or other sulphuret, and sulphur are placed. *d* a lid or cover through which the materials are introduced; and E′ a fireplace by which the pot is heated. F is a pipe leading from the boiler into the head of the pot E; and *a* a cock by which it is opened and closed. G¹ is a pipe leading from the top of the pot E to the chamber A, and *b* a cock by which it is opened and closed. H is a safety-valve attached to the boiler, and K a safety-valve attached to the chamber A. I is a thermometer to indicate the temperature. The mode of operating with the apparatus is as follows:—The boiler-furnace is first lighted, and when the safety valve indicates an approach to a temperature of 280° Fah., the other furnace is lighted which is to volatilize the orpiment and sulphur. The cocks *a* and *b* are then opened, and the steam allowed to pass off through the pipes F and G, and head of the pot E, into the chamber A, containing the material, in order that they may be thoroughly heated before being sulphuretted. After a short time fumes from the orpiment and sulphur begin to ascend and mingle with the steam. In this state I leave matters for a period varying from half an hour to two hours, according to the thickness of the materials operated upon. I then close, by means of the cock *b*, the passage to the chamber A, draw or damp the fires, raise the safety-valve K, and when the chamber A has been cleared of vapors, remove the sulphuretted materials. The safety-valve H is kept, all the time the sulphuretting process is going on, at a little higher pressure than the safety-valve K, in order that there may be a current in the direction of the chamber A. L is a cock by which the condensed water, which accumulates in the chamber A, is drawn off.

The calenders, represented by Figs. 2241 and 2242, as used in the manufacture of driving-bands and sheets of gutta percha, at the Gutta Percha Works of Brooklyn, New York, have rolls 6 feet 4 inches in length, and 22 inches in diameter, and each roll will weigh about 7000 pounds. The rolls are heated by steam.

GYRATION, *the centre of*, is that point in which, if all the matter contained in a revolving system were collected, the same angular velocity will be generated in the same time by a given force acting at any place as would be generated by the same force acting similarly in the body or system itself.

The distance of the centre of gyration from the point of suspension, or the axis of motion, is a mean proportional between the distances of the centres of oscillation and gravity from the same point or axis.

If S represent the point of *suspension*, G the place of the centre of *gravity*, O that of the centre of *oscillation*, and R that of the centre of *gyration*. Then,

$$SR = \sqrt{SO \cdot SG} \; .$$

and $SO \cdot SG$ = a constant quantity for the same body and the same plane of vibration.

END OF VOL. I.